THE CAMP BAKER QUARRY (24ME467): 2001

BLM

Montana State Office

By
Tom E. Roll and Michael P. Neeley

with
Appendices by:
Robert J. Speakman and Michael D. Glascock
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Department of Sociology and Anthropology
Montana State University
2003

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and
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Many people made substantial contributions to the Camp Baker Quarry project. Members of the field crew consisted of Justin Garrison, Marshall James, Aaron Kind, and Orrin Koenig. The success of the project depended on their continual and concentrated efforts. Orrin Koenig assumed responsibility for much of the photography and stratigraphic drawing. He also contributed more than his share to the cooking, clean-up, and general organizational effort that accompanies any small-scale project. Justin Garrison took on the task of washing and size-sorting the debitage; he devoted much of the summer of 2001 to that job. Ben Calnon performed the vast majority of the actual debitage analysis. He worked closely with Mike Neeley and Tom Roll throughout the winter of 2002-03 to get most of that analysis finished. Mike Neeley, Assistant Professor of Anthropology at MSU, participated in the project from the onset. With good-humor, he helped get the excavations underway and oversaw excavations during the brief intervals when he wasn't participating in the seemingly endless hours spent on the planimetric survey. He also contributed substantially to the methods employed in the lithic analysis.

Residents of the Smith River area close to Camp Baker provided substantial support to the project. Jock and Jamie Doggett of the Camas Creek Sheep and Cattle Company graciously allowed us to use their bunkhouse as field headquarters free of charge. The mid-May snowstorms and rain showers would have been far more formidable had we been obliged to work from a tent camp. As hosts, they were beyond compare. Donald and Becky Johnstone, whose property surrounds the BLM inholding that contains the Camp Baker Quarry, have endured a sporadic stream of archaeologists begging permission to cross their property to access the site. We gratefully acknowledge their continued good will and interest.

Jerry Clark, Great Falls Resource Area Archaeologist for the BLM, has shown continued interest in the project and met with us on a number of occasions to provide input and physical support by participating in the acquisition of raw material for the sourcing studies. Without Jerry's continued involvement, the success of the project would have been far more limited.

ABSTRACT

A Montana State University field crew conducted archaeological investigations at the Camp Baker Quarry in central Montana. Work accomplished by a six-person crew over a ten-day period consisted of detailed planimetric mapping of the quarry area and test excavations on the edges of two quarry pits. The excavations yielded a limited number of formed artifacts and approximately 14,000 pieces of debitage. Analysis of the debitage resulted in the conclusion that work in that portion of the quarry examined consisted primarily of raw material extraction, testing of raw material for quality, removal of undesirable portions from the extracted blocks, and the production of blocky cores and flake blanks for subsequent tool manufacture at other locations. The project found virtually no evidence for biface core production, tool manufacture, or tool maintenance.

An ancillary part of the project involved foot reconnaissance of BLM lands surrounding the Camp Baker Quarry. Limited reconnaissance was initiated in the summer of 2001 and continued on an intermittent basis through autumn 2002. Significantly, a nearly continuous band of quarry pits stretch for about 3.5 km southwest from Camp Baker. The reconnaissance also discovered a number of very large concentrations of flaking debris and several small tipi-ring sites on south and east facing open slopes overlooking the Smith River. The area surrounding the Camp Baker Quarry must have been an important location for stone acquisition and other activities.

A cooperative endeavor with M.D. Glascock and R. J. Speakman of the Archaeometry Laboratory at the University of Missouri Research Reactor resulted in chemical characterization of toolstone from the Camp Baker Quarry with laser-ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS). Encouraging initial results led to expansion of the project to include toolstones from two additional quarries in the Smith River Area and five other quarries in southwestern Montana. At present, the results are inconclusive, but offer intriguing possibilities for future research characterizing toolstone sources in Montana and elsewhere.

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I INTRODUCTION

During the spring of 2001, MSU archaeologists conducted fieldwork at the Camp Baker Quarry (24ME467). Named for the nearby Camp Baker recreational site, the Camp Baker Quarry perches on the east slope of the Dry Range about 400 m west and 100 m above the nearby Smith River. The small, aptly named Dry Range lies between the Big Belts on the west and the Little Belts to the east. A mixed Ponderosa Pine/Douglass Fir forest typical of the mountainous terrain in this part of Montana dominates the upper story of vegetation (Figure 1). Assistance Agreement 1422E30A980017 between the BLM and MSU provided the mechanism to undertake this work. Initial work consisted of detailed surface mapping of the terrain in the immediate vicinity of the quarry pits and test excavations in two of the pits. Subsequent to the mapping and testing phase the project continued with foot reconnaissance of surrounding BLM lands, carried out on an intermittent basis through the autumn of 2002. Laboratory work focused on cleaning and analysis of the limited formed artifact assemblage and approximately 14,000 pieces of debitage recovered during the excavations. Chemical characterization of Camp Baker chert using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) represents an important ancillary element of the project. This later undertaking involved the Archaeometry Laboratory at the Missouri University Research Reactor with partial support from both the University of Missouri and the National Science Foundation.

Figure 1. Camp Baker Quarry on east slope of Dry Range (view to west).

II BACKGROUND

Slowly, the significance of the lithic resources contained by the Smith River corridor to prehistoric people has begun to emerge. Among members of the Montana archaeological community, folk knowledge of quarry use along the Smith River has considerable time depth. A U.S.G.S 1:250,000 White Sulphur Springs Quadrangle map in the map collection of the Department of Sociology and Anthropology, Montana State University, has the locations of prominent archaeological sites annotated in pencil. The annotations, made during the early 1970s by John Darroch, a long-term resident of the Livingston, Montana vicinity, include the Doggett Quarry. John spoke of the quarry as common knowledge to locals. The Montana Cultural Resource Information System (CRIS) does not identify the site by name, but a site report form prepared by George Knight, dated August 29, 1976, places 24ME69 at the same physical location as the Doggett Quarry. In *Models for Deriving Cultural Information from Stone Tools,* Robson Bonnichsen (1977) refers to the "VanAuchen-Doggett Quarry" near the Smith River.

Although perhaps first in the attention of professional archaeologists, the Doggett Quarry now appears as one of a number of quarries along the Smith River corridor that exhibit intensive use (Figure 2). Steve Aaberg (1983) recorded the Camp Baker Quarry in 1979, though local ranchers and prospectors probably knew of it much earlier. Located about 13.25 km north of the Doggett Quarry, the Camp Baker Quarry consists of a concentration of pits and depressions in a total area of less than 2 ha. These and a number of other quarries in the Dry Range generally occupy elevations between 1450 and 1600 m. a.m.s.l. Geologically, this zone contains sediments of Cambrian through Devonian age (Hruska 1967), with the Camp Baker Quarry a short distance down slope from the Park Shale/Pilgrim Limestone (Cambrian) contact. About 3.3 km WSW of Camp Baker another quarry site, 24ME332, contains chert deposits associated with Devonian age Jefferson Dolomite. In most instances, Tertiary igneous intrusions probably contributed to the formation of local chert deposits regardless of the age of associated bedrock.

Foot reconnaissance between Camp Baker and 24ME332 identified 11 additional concentrations of quarry pits (Figure 3). Those eleven clusters exhibited neither the quantity nor size of pits present at Doggett, Camp Baker or 24ME332. A newly reported quarry, a short distance east of Songster Butte, about 4.4 km north of Camp Baker, occupies a somewhat smaller area than either Doggett or Camp Baker, but, based on the surface examination of lithic debris, contains similar and equally suitable lithic raw material.

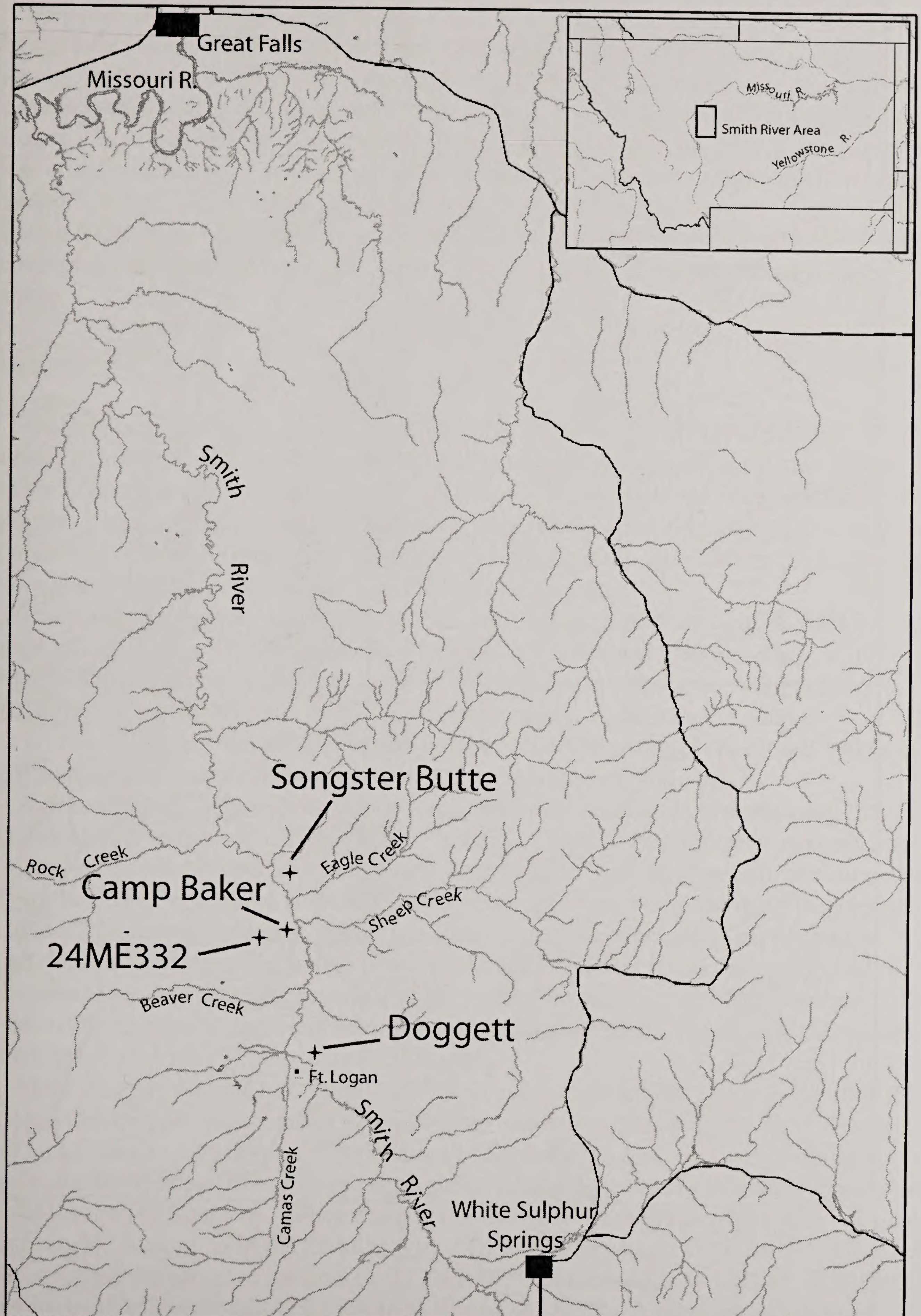


Figure 2. Prominent Smith River quarries in relation to major settlements and features.

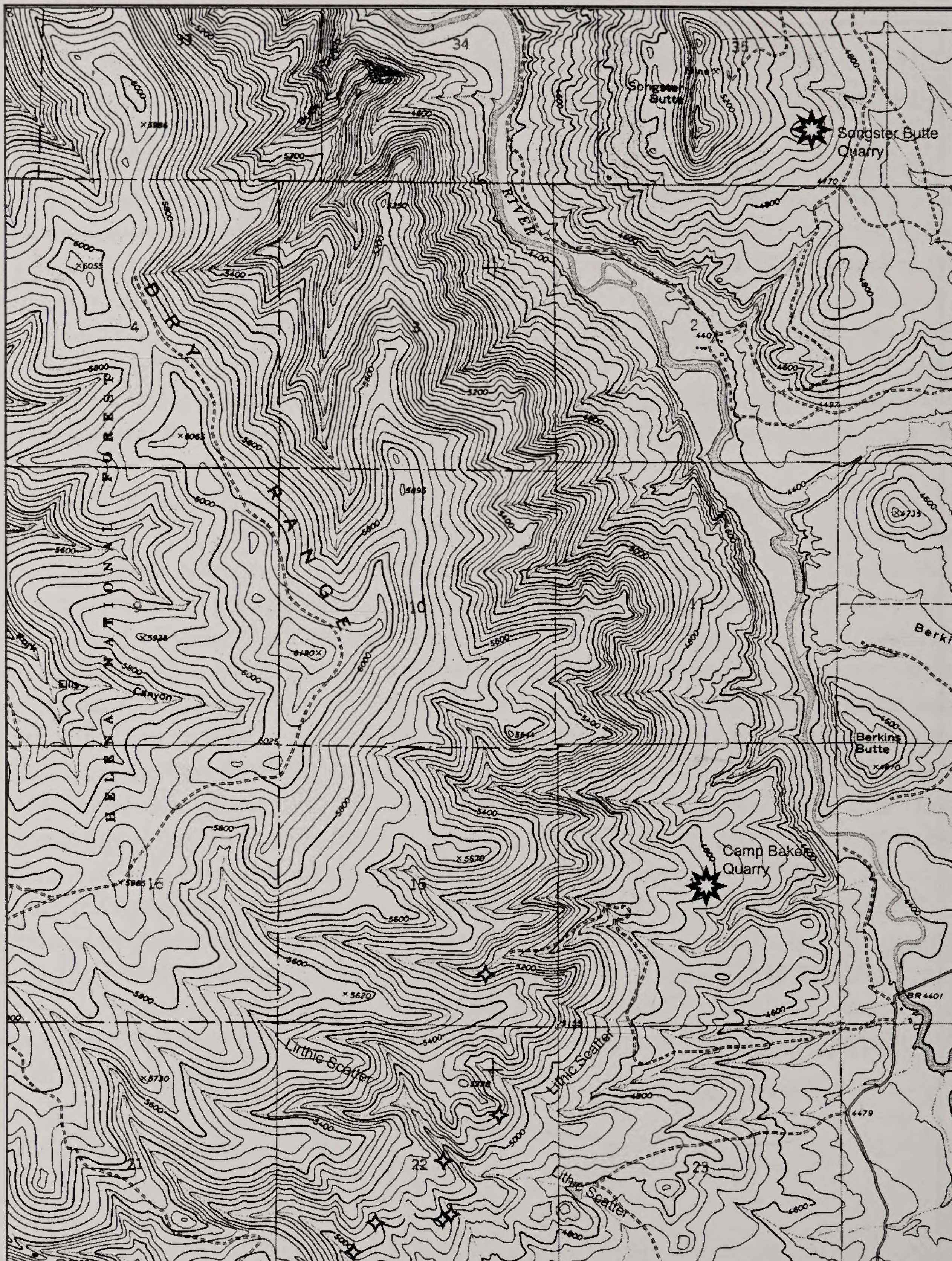


Figure 3. Identified quarry locations in the vicinity of the Camp Baker Quarry.

III FIELD WORK

The research undertaken as part of the Camp Baker project was intended to provide preliminary information about the Camp Baker Quarry and its immediate vicinity. As a result, the work stressed acquisition of basic archaeological data. Primary goals included the production of a usably accurate topographic map of the quarry area, test excavation of one or more quarry pits to ascertain the context within which quarrying took place, and acquisition of sufficient artifacts/debitage to evaluate the nature of the lithic acquisition and reduction strategy at the quarry location. A secondary aspect of the project involved foot reconnaissance of surrounding BLM lands for potentially associated ancillary activity areas. Finally, the chemical characterization of the Camp Baker chert emerged as an additional research venue of high importance.

A Mapping

The production of an accurate topographic map of the quarry area provides the foundation for many subsequent aspects of site evaluation and interpretation. Although not undertaken in detail at this time, estimates of the quantity of raw material extracted, the methods of extraction, patterns of quarry activity over time, energy expended in quarrying and many other issues involving prehistoric quarrying activities depend upon a topographic map that accurately delineates quarry features and their associations with one another.

The planimetric survey undertaken at the Camp Baker Quarry utilized a Sokkia PowerSet 1000 total station (Figure 4). The instrument features self contained data recording, a 30X telescope, horizontal and vertical angle accuracy to 1.0" and, in conjunction with the single glass reflecting prism used for this project, distance accuracy, under average conditions, of ±(2 + 2ppm x D) mm @ 1m to 2400 m. Given that distance observations rarely exceeded 100 m, the potential accuracy of the instrument far exceeds the requirements of the task.

A dense Ponderosa Pine/Douglas Fir forest has established itself in and around the sloping, undulating terrain of the Camp Baker Quarry. In fact, surface moisture concentrated in the quarry pits probably contributed to the relatively higher density of trees in the immediate vicinity of the quarry. The rapid slope toward the south, combined with the dense vegetation, created some difficulties in finding appropriate stations to achieve complete survey point coverage of the quarry area. The nature of the topography and vegetation required a total of eight stations to achieve adequate coverage of the immediate quarry area, approximately 10,000 m^2. Fortunately, because of more open terrain surrounding the quarry, the same eight stations permitted survey coverage of more than 40,000 m^2.

More than any other factor, visibility from an established turning point determined the location of subsequent points. Station A, the primary site datum, was placed a short distance north of an existing two-track road. The location of Station A proved extremely fortuitous. Originally, the BLM hoped to have a cadastral survey team in the area to locate the vertical and horizontal location of Station A. When those plans changed, the BLM provided a survey grade GPS instrument. According to the BLM-provided GPS and the project GPS, Station A lies less than a meter from the center of Section 14, T12N/R4E, UTM Zone 12, 485282.95, 5182889.16, at an approximate elevation of 1472.5 m (4830 ft) a.m.s.l. Station A received an arbitrary horizontal designation of 1000 m. N/E 1000 m. and 1472.5 m elevation.

Figure 4. Starting planimetric survey of Camp Baker Quarry, Spring 2001. (Left to right, Justin Garrison, Marshall James, Tom Roll, Aaron Kind, Mike Neeley.) (Photo by Orrin Koenig.)

The path cleared to create the two-track permitted line-of-sight projections from Station A to Stations B (to the east) and C (to the west), a total distance of 140 m. Projection from Station C permitted establishing Station D; from Station D, Station E; and from Station E, both F and G, all along the west and south margins of the quarry area. From Station B, setting Station H along the eastern side of the quarry permitted closure with Station F. Physical station markers consist of 1.6 cm diameter by 50 cm long steel concrete reinforcing bar with aluminum survey caps. Each survey cap contains an engraved station designation and a center punch mark to permit centering a surveying instrument.

The actual survey turned into a daunting task. While part of the crew devoted itself to establishing Stations A, B, and C, the remainder initiated the process of trying to locate and identify each individual quarry pit. They began by placing pin flags in the center of each pit. Once they believed they had identified all of the pits, one individual set about providing pit numbers, starting on the northwestern edge of the pit concentration and proceeding around the periphery to the western edge of the pit concentration. From that point, he attempted to maintain a zigzag pattern until he had numbered all pits. As the crew came to know the terrain better, they identified additional pits. Identifying and numbering a series of pits in a quarry setting sounds like a straightforward project, but a number of problems emerged. Several large pits contained a number of smaller pits. In other instances, it appears that use expanded a pit to incorporate pre-existing pits. As a result, the number of pits present at the Camp Baker Quarry remains somewhat indeterminate. The presence of large saw-cut stumps attests to an episode of historic

logging, and a few burned snags suggest the possibility of forest fires in earlier times. Some of the pits in the area clearly result from dozer activity. In some instances, unambiguous evidence for historic origin exists, as indicated by the presence of historic artifacts, rectangular pit shape, and berm configuration; in others, the distinction is more equivocal. In particular, the origin of six pits outside the main concentration and north of the two-track remains uncertain, as does that of Pit 37 on the southeastern edge.

A simple protocol dictated the readings taken during the project. Survey required a minimum of two people, one to take readings and another to run the prism pole. The individual operating the total station (Mike Neeley or Tom Roll exclusively) directed prism placement for each shot. Much of the time, a third person cleared vegetation to clear the field of view (Figure 5). At minimum, readings were taken at or near the lowest attainable point of each pit. Despite careful placement of the survey stations, and considerable clearing of both trees and undergrowth, occasionally the desired location proved impossible to use as a sighting point. If a pit contained multiple depressions, records included the approximate low point of each. Where possible, shots included the upslope edge of the pit and the crest of the down slope berm. Shots were also made on the lateral edges of the pits (approximately E-W) when possible. When practical, shots made along visible slopes between pits increased the density of survey points. Lastly, shots delineated the bottom of the main drainage to the south of the quarry and the N-S flowing tributary drainages that bracket the east and west sides. In addition to the survey, taped length-width measurements using compass orientation and sketches for each pit provided another measure of control.

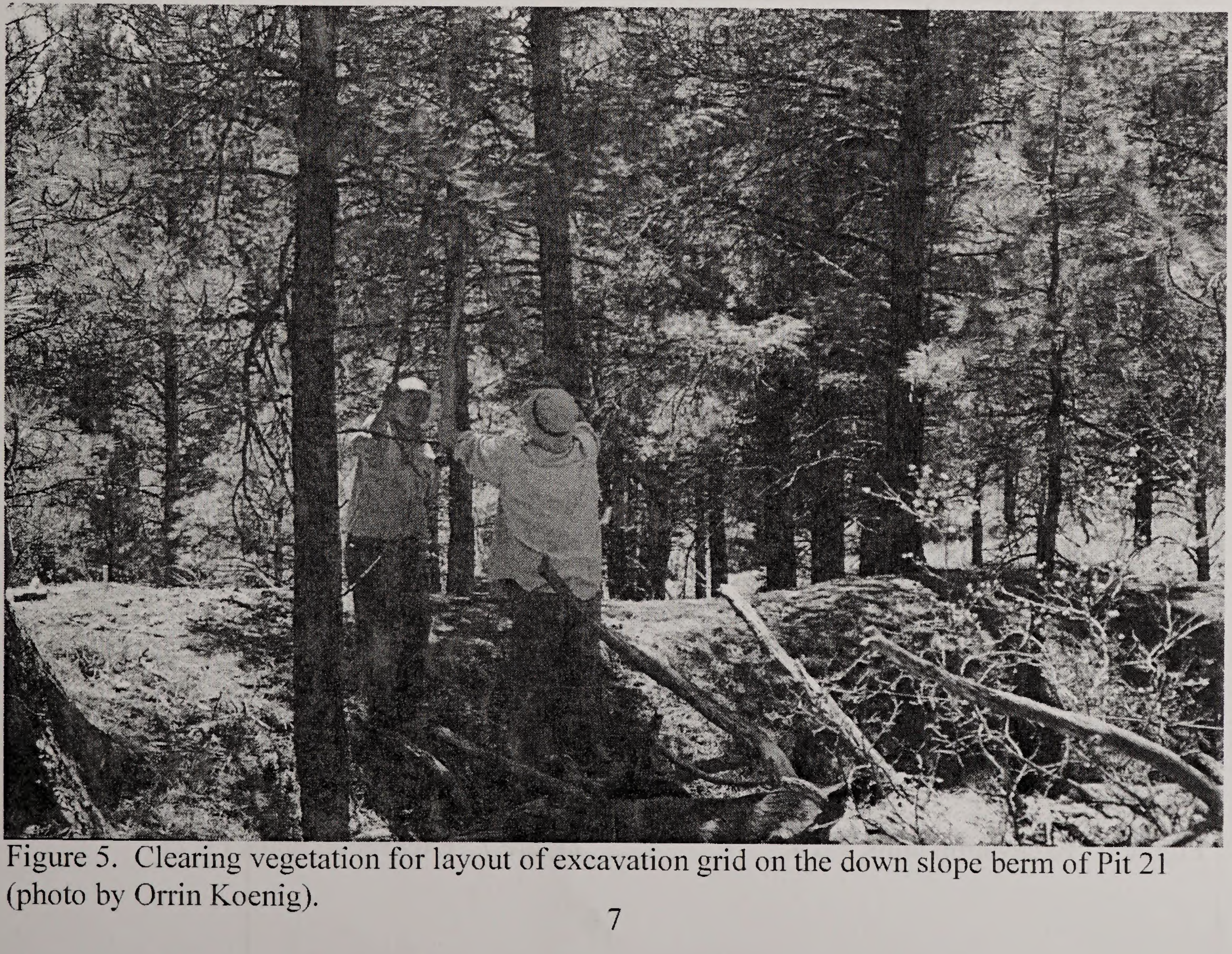


Figure 5. Clearing vegetation for layout of excavation grid on the down slope berm of Pit 21 (photo by Orrin Koenig).

After data cleaning, 422 individual survey points provided the basis for creating a topographic map. Microsoft Access and Excel aided in the manipulation of the data. AutoDesk Land Desktop 2000 was used to create the final topographic map of the site (subsequently upgraded to Land Desktop 2002). The use of a vector graphic system permits scaling maps to virtually any desirable size.

The final map displays a total of 68 pits (see Map 1). Numbers run from 1-72 with numbers 47, 49, 68 and 71 deleted. While numbering pits, numbers 47 and 49 were missed and the pits numbered 68 and 71 were identified as the result of historic activity. From the highest (most northerly) survey point to the lowest (the bottom of the drainage on the south) constitutes an elevation change of about 42 m. Within the main cluster of pits, elevation change from Pit 5 to Pit 62 exceeds 16.5 m over a horizontal distance of 122 meters, about 1 m vertical for each 7.4 m. horizontal.

B Excavations

Excavations consisted of test units on the down slope berms of Pits 4 and 21 (Figure 6 and Figure 7). The total station was employed to lay out the excavation units and to establish an elevation datum for each pit. For ease of calculating elevation from a level line, each pit received a vertical datum designated +100.00 m. This was subsequently related to the elevation of survey Station A. Excavation tools included shovel and trowel with occasional use of a pick or spud bar to dislodge large cobbles. During excavation, dry screening of all removed sediment through 6 mm mesh (4 per inch) hardware cloth separated observed tools and lithic debitage from general quarry debris. Typically, two screeners managed to keep up with one excavator, but occasionally the quantities of debitage required the excavator to pause and participate in separating debitage from quarry debris. The excavations proceeded in arbitrary 10 cm levels for all of Pit 4 and for the first three levels of Pit 21. Because of large cobbles in the matrix and little apparent change in sediment, 20 cm levels prevailed after the third 10 cm level in Pit 21.

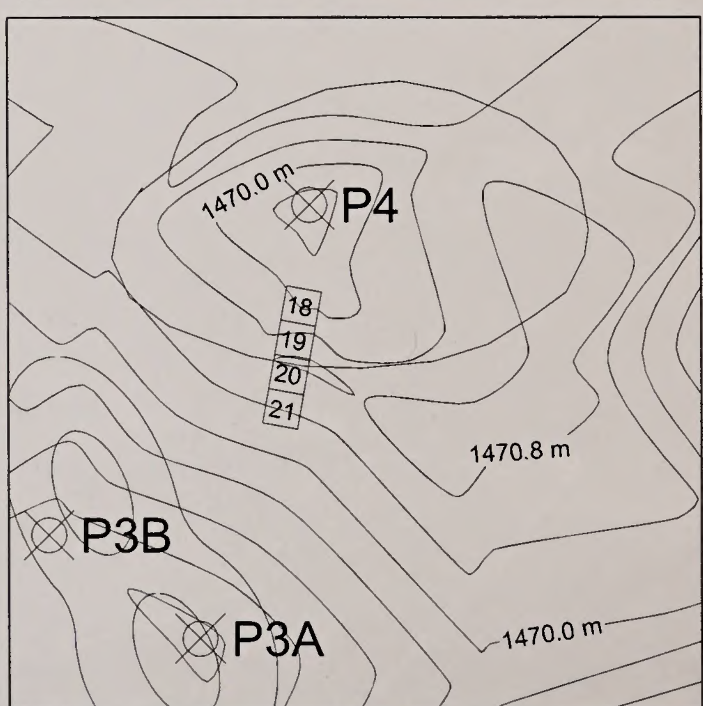


Figure 6. Excavation units, Pit 4.

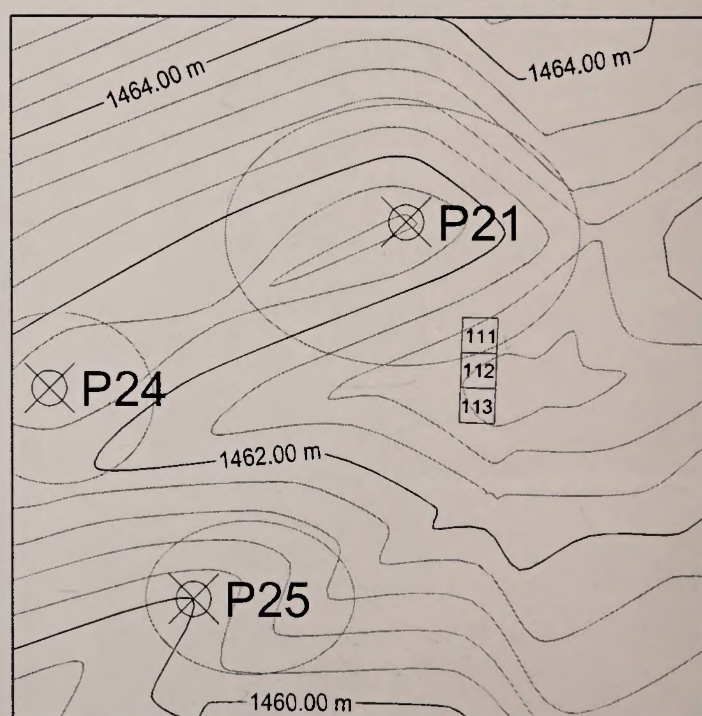
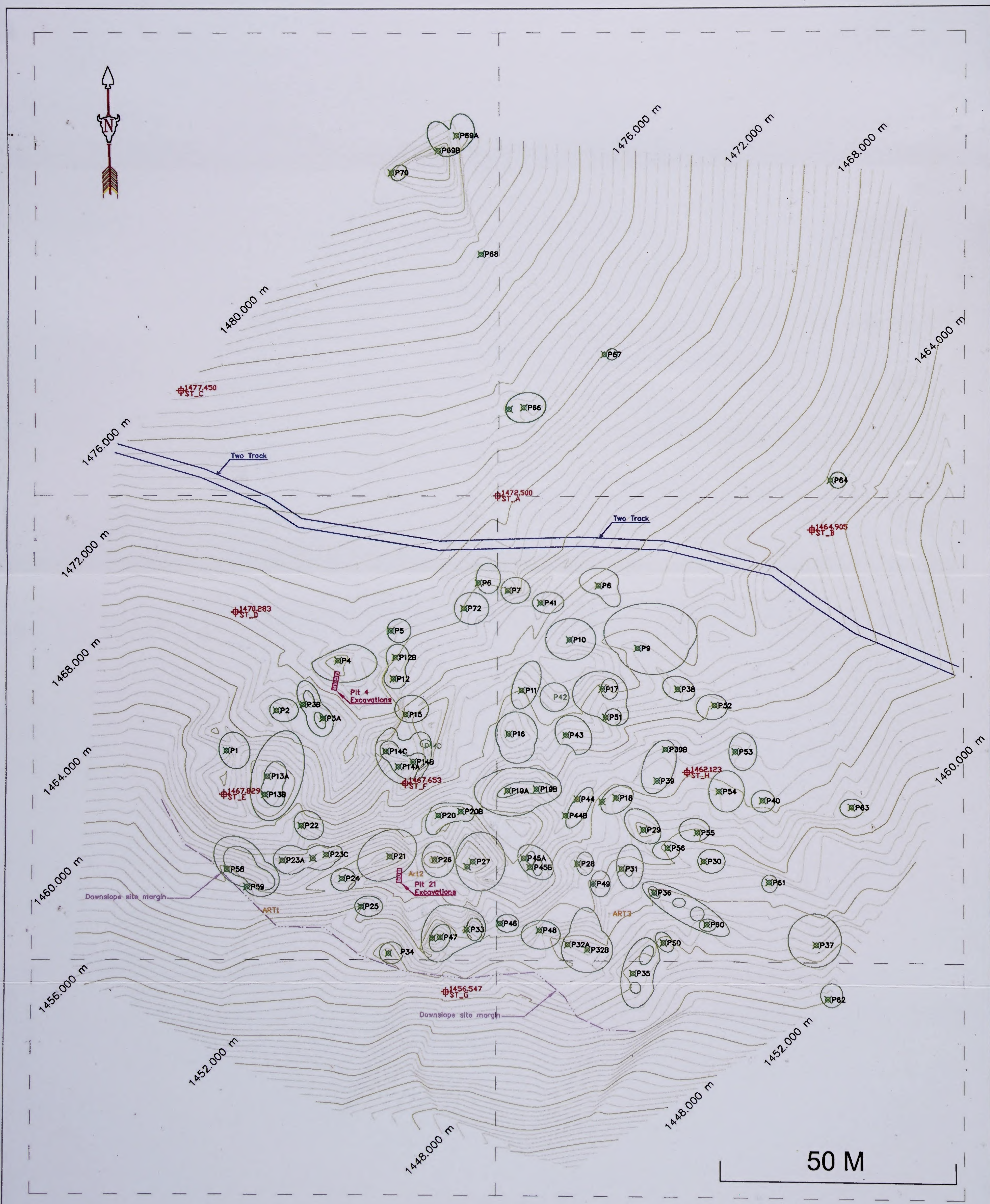


Figure 7. Excavation units, Pit 21



Map 1. Camp Baker Quarry, 24ME476

Contour inverval 0.40 m.

1 Pit 4 Excavations

Pit 4 lies on the NNW edge of the main quarry pit concentration. The pits in this portion of the site display both smoother profiles and greater accumulation of organic matter (duff) than those farther down slope. For those reasons, we surmised they might represent a somewhat earlier interval of use. In addition, a smaller pit with a smaller berm promised the possibility of exceeding the maximum depth of cultural deposits before exhausting our scheduled time, thus presenting the possibility for additional testing elsewhere.

Excavation began in Pit 4 with a series of 1 x 1 m excavation units that created a N-S trench (Figure 6, Figure 8, and Figure 9). Excavations in Pit 4 attained a maximum depth of about 55cm below surface, but because of the relatively steep slope on either side of the berm crest, excavations required a total of 10 levels below datum. The west wall profile revealed four main strata capped by 2 - 4 cm of conifer needle duff. Debitage and quarry debris (angular cobbles) in a sparse coarse silty sand matrix constituted the upper three strata. Because the three strata exhibited essentially the same sediment color and texture with little sign of soil development, differentiation of the three strata depended mostly on size and frequency of fractured cobbles. Decomposing bedrock of Park Shale or associated mudstones comprised Stratum 4; at that stage continued excavation became futile (Figure 10 and Table 1). Total volume excavated from the four units opened (18, 19, 20, and 21) amounted to approximately 1.25 m^3. Excavations in Pit 4 consumed 12 persondays.

Figure 8. Beginning excavations in Pit 4, view to SSE.

Figure 9. West wall of excavation in down slope berm of Pit 4 (view to west).

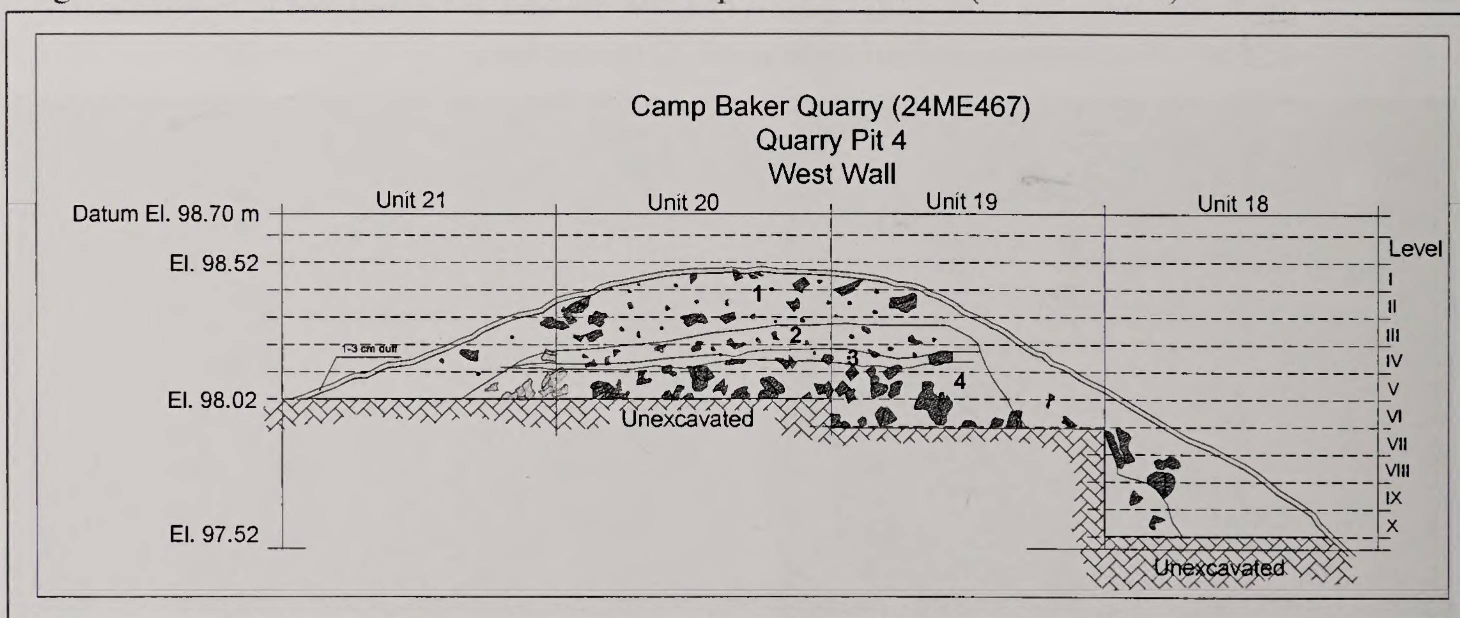


Figure 10. Stratigraphic profile of west wall excavations through down slope berm of Pit 4 (from original by Orrin Koenig).

Table 1. Stratigraphic description of west wall, excavation through down slope berm of Pit 4.

Stratum	Description
1	Coarse Sand, Angular, >50% particle size #5.0 mm, to \$1.0mm, 5YR4/3 (Reddish Brown), dry.
2	Coarse Sand, \$1.0mm/Avg. 2.0-2.5mm/#5.0 mm, 5YR5/4 (Reddish Brown), dry, angular cobbles decrease with depth, cobble size increases with depth.
3	2.0 –4.0 cm of sandy clay loam 7.5YR41 (Brown – Dark Brown), moist.
4	Highly fractured bedrock, mudstone/shale, 10YR6/1 (gray), dry.

2 Pit 21 Excavations

Pit 21, about 43 m SSE and 18 m lower than Pit 4, is a relatively large pit with a prominent down slope berm. Measured from the crest of the down slope berm, the maximum depth of Pit 21 exceeds 2.0 m. At about 13.5 m on the long axis and 10 m on the narrow axis, the pit stands out as one of the larger pits at Camp Baker (though far from the largest). The selection of Pit 21 reflected our desire to examine one of the larger berms without tackling one of the really large pits in the time remaining. In addition, its proximity to Station F eased the problem of establishing control points to lay out the excavation grid and elevation datum.

Test excavations in Pit 21 opened three 1 x 1 meter units (units 111, 112 and 113) (Figure 7 and Figure 11). After clearing the duff and one 10 cm level from the three units, work focused on units 112 and 113; unit 111 was abandoned. Excavations in units 112 and 113 attained a maximum depth of 140 cm from surface. By adopting 20 cm levels after level three, work progressed with sufficient speed to finish up by the end of our allotted field time. Six discernable strata became apparent in the profiles created by the excavation. Sediment consisted of a silty-sand matrix containing a high frequency of debitage and quarry debris Figure 12, (Table 2) and Figure 13. In Stratum 2, debitage seemingly represented a greater fraction than either the silty sand or quarry debris. In that stratum, the high quantities of loosely consolidated debitage precluded maintaining vertical pit walls and a number of slumps composed almost exclusively of debitage occurred during excavation. A somewhat decreased, but still high, frequency of debitage continued to the limits of excavation. Because of the

Figure 11. Pit 21 excavations underway. View to south.

slumping, continuation of the excavation to greater depth would have required opening at least two additional units to make it sufficiently safe for excavators to work. Excavations in Pit 21 required 18 persondays. Including the small amount excavated in unit 111, the volume excavated from the down slope berm of Pit 21 totaled about 2.75 m^3.

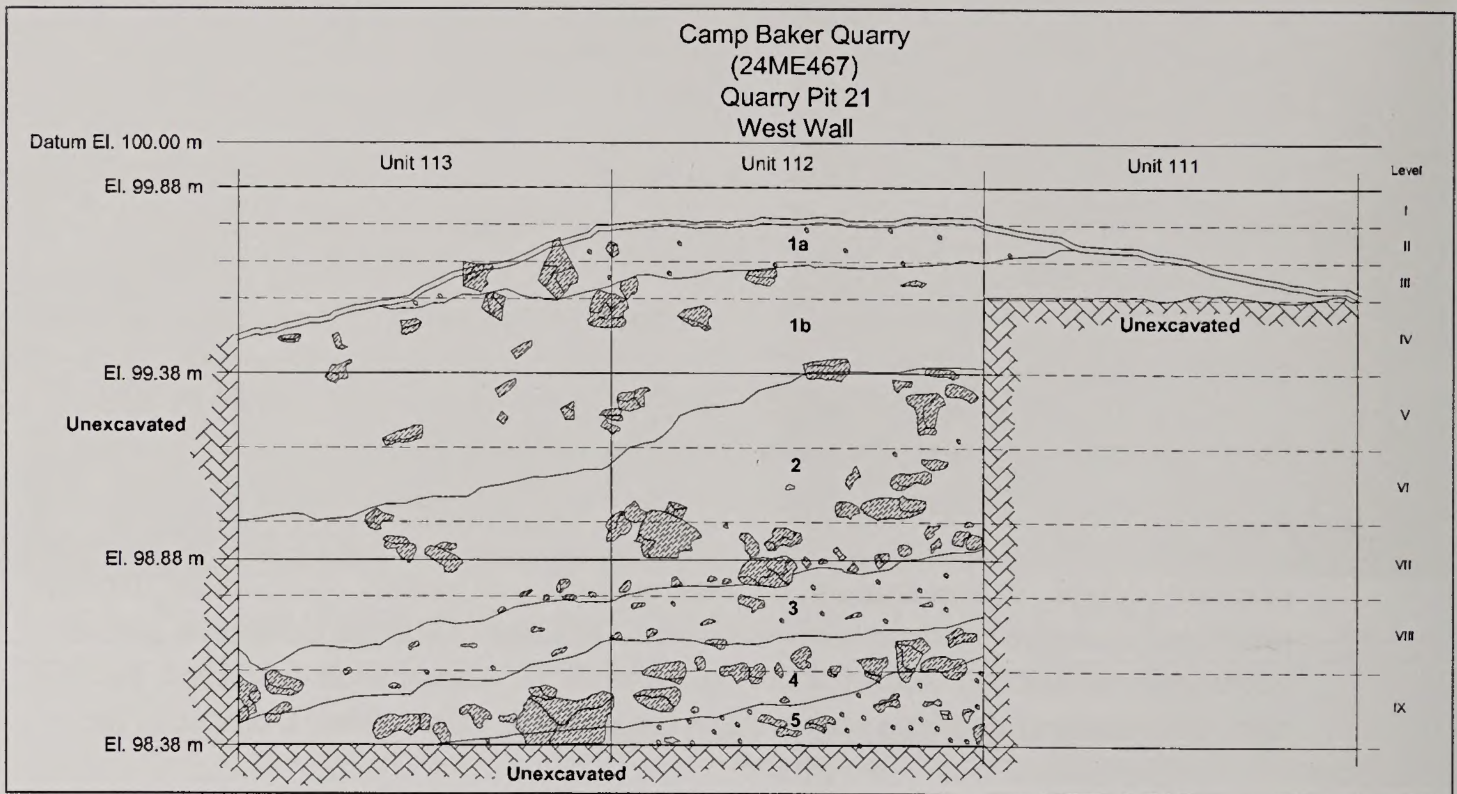


Figure 12. West wall stratigraphy of excavations in down slope berm of Pit 21 (original by Orrin Koenig).

Table 2. Stratigraphic description of west wall, excavation through down slope berm of Pit 21.

Stratum	Description
1a	Silty sand, ≤ 2.0 mm, average 0.5mm particle size, 5YR7/6 (Strong Brown).
1b	As in Stratum 1a, with addition of roots.
2	Sparse silty sand with unconsolidated quarry debris.
3	Silty sand, ≥0.1 mm - ≤0.5 mm, avg ~0.25 particle size, 7.5YR5/6 (Strong Brown)
4	Sand, ≥0.1 mm ≤1.0 mm, avg. >0.25 mm, 7.5YR5/4 (Brown), abundant cobbles.
5	As in Stratum 4, with reduced frequency of cobbles.

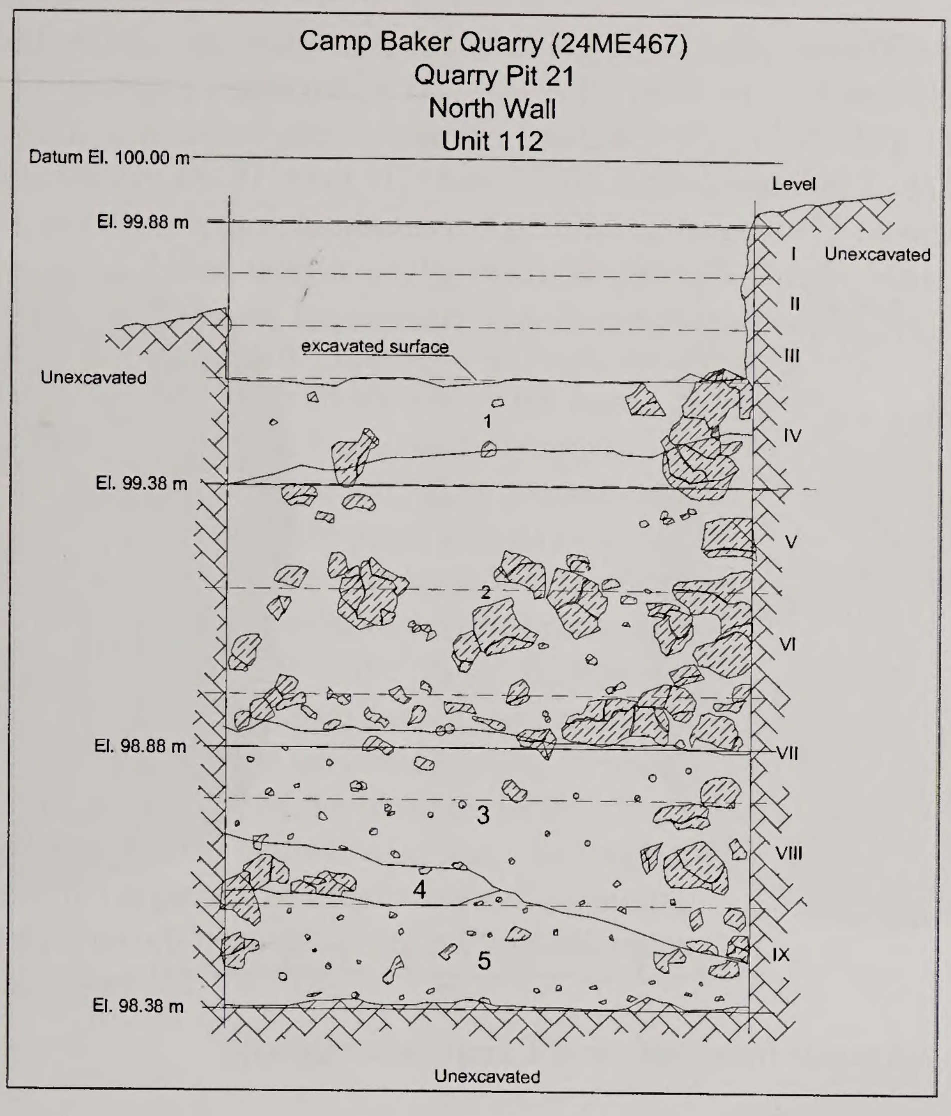


Figure 13. North wall stratigraphy, excavation in down slope berm of Pit 21 (original by Orrin Koenig).

IV ARTIFACTS

A Grooved Mauls

The excavations yielded very few formal artifacts. Conducting the planimetric survey and moving equipment between locations resulted in surface discovery of three fragmentary grooved mauls manufactured from rounded outwash quartzite cobbles. Two of the specimens retain approximately one-half of the maul (Figure 14). At some time in their use history, they had been split along the long axis of the maul. Subsequent use battered away the sharp margin formed by the break and the cortical edge. Both half-specimens exhibit very heavy use on both ends. The third fragment of grooved maul represents approximately 20 percent of the original specimen and consists of a spall containing a small section with the pecked/ground groove typical of such mauls. Table 3 provides basic metric data for the three grooved mauls.

Figure 14. Grooved mauls from surface of Camp Baker Quarry.

Table 3 . Grooved mauls from surface of 24ME467, basic metric data.

Pit	Level	No.	Artifact	Material	Length (mm)	Width (mm)	Thick (mm)	Weight (g)	Groove Width (mm)	Groove Depth (mm)
Gen	Surf	1	grooved maul	quartzite	125.3	100.4	63.5	1081	15	2.8
Gen	Surf	2	grooved maul	quartzite	122.7	97.9	69.6	1017	23	5.4
Gen	Surf	3	grooved maul	quartzite	123.8	92.1	38.3	459	18	2.64

B Projectile point

While screening, excavators found a single projectile point (Figure 15) consistent with the Old Women's Phase (ca. A.D. 750 – A.D. 1800) of the Late Prehistoric Period (Reeves 1969). It received catalog number 24ME467/P21/113/VIII/2, indicating the Camp Baker Quarry, Pit 21, Unit 113, Level VIII, artifact number 2. Manufactured of a white chert, the mensuration attributes are as follows: length—33.68 mm, width—13.78 mm, thickness—3.4 mm, weight—1.1g, blade length—25.47 mm, blade width—13.78 mm, base length—7.54 mm, base-width—13.78 mm, neck width—10.55 mm, notch width right—2.55 mm, notch width left—1.9 mm, notch depth right—2.13 mm, notch depth left—0.98, base concavity width—13.20 mm, base concavity depth—1.42 mm. Qualitatively, it may be described as a small, basally indented side-notched projectile point with a triangular outline, excurvate lateral blade edges, random retouch pattern, transverse retouch penetration (some retouch extends beyond the centerline of the blade), biconvex cross section, base thinned by pressure flaking, possessing no evidence of grinding around the basal margin. A small portion of one lateral edge of the base is missing. It came from a depth of about 80 cm below surface. Although found in the screen, the sequence of excavation and screening suggest that it derived from the lower portion of Stratum 2 as shown in Figure 12.

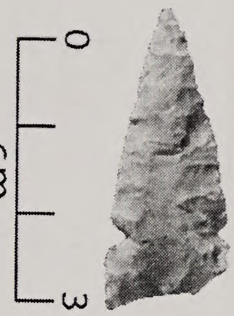


Figure 15. Projectile point.

C Hammerstones

Table 4 itemizes the complete tool assemblage from all excavations. Excluding debitage, it includes all items of apparent human use or manufacture and several questionable items such as chert nodules (4), a small piece of antler or bone with no apparent deliberate modification, and a tiny piece of tooth enamel. Hammerstones (7 complete or nearly complete) (Figure 16) and hammerstone fragments (20) composed the only class of unchipped stone in the excavated assemblage.

Figure 16. Hammerstone from Stratum 2, Pit 21.

Table 4. Non Debitage Items found during excavation.

Pit	Unit	Level	Number	Type	Mod	portion	Mat	color	Length (mm)	Width (mm)	Thick (mm)	Wt (g)
4	19	III	1	hammerstone	battered	complete	quartzite	tan	90	69.8	39	390.9
4	19	IV	1	modified cobble	battered	distal frag	argillite	gray	90.1	48	23.4	161.9
4	19	IV	2	hammerstone	battered	complete	quartzite	pink	71	56	37.4	173
4	21	III	1	hammerstone	battered	complete	quartzite	buff	56.4	51.5	45.7	149.9
21	111	II	1	frag		internal frag	quartzite	tan	62.1	52.5	11.6	42.3
21	111	II	2	frag		internal frag	quartzite	gray	141.3	83.2	44.1	575
21	111	III	1	Bone/antler Frag		medial frag	bone/antler		68.9	20.1	10	6.8
21	111	III	2	frag		internal frag	quartzite	gray	56.8	35.2	9.4	14.8
21	111	III	3	frag		internal frag	quartzite	gray	26.9	19.4	8.6	4.3
21	111	III	4	concretion		complete	chert	cream	81.1	39.7	19.1	59.9
21	112	I	1	frag		internal frag	quartzite	red	48.1	43.6	13.6	23.5
21	112	II	1	frag		internal frag	quartzite	tan	34.2	27.4	5	4.2
21	112	II	2	frag		internal frag	quartzite	tan	49.4	29.5	6.2	8.3
21	112	II	3	frag		internal frag	quartzite	tan	77.9	36	15	40.3
21	112	II	4	frag		internal frag	quartzite	tan	68.3	56.9	9.4	35.7
21	112	II	5	frag		cortical frag	quartzite	tan-red	83	80.1	20.2	156.7
21	112	II	6	concretion		complete	chert	cream	43.8	39.7	38.2	55.2
21	112	II	7	hammerstone	battered	complete	quartzite	tan-red	87.3	68	50.3	423
21	112	V	1	frag		cortical frag	quartzite	Tan	83.5	43.7	20	82.9
21	112	VI	1	frag		cortical frag	quatzite	tan-gray	49.6	26.8	22.6	33.4
21	112	VI	2	frag		internal frag	quartzite	tan	23.3	10.8	6.5	1.6
21	112	VI	3	hammerstone	battered	complete	quartzite	reddish	67.8	56.6	33.1	189.5
21	112	VI	4	hammerstone	battered	complete	quartzite	tan	84.5	68.3	42.7	388.1
21	112	VII	1	frag		internal frag	quartzite	red	36.6	25.8	6.9	5.5
21	112	VII	2	Hammerstone frag		frag	quartzite	tan	66.8	51.8	29.5	140.4
21	112	VII	3	frag		internal frag	quartzite	tan	59.6	52.1	11.9	31
21	112	VII	4	hammerstone		frag	quartzite	white	65.5	37.3	34.6	68.2
21	112	VIII	1	frag		cortical frag	quartzite	brown	41.7	28	12.7	14.3
21	112	VIII	2	frag		cortical frag	quartzite	brown	34.3	35	8.7	13.7
21	112	VIII	3	concretion		complete	chert	cream	66	44	43.3	107

Table 5 (continued). Non Debitage Items found during excavation.

Pit	Unit	Level	Number	Type	Mod	portion	Mat	color	Length (mm)	Width (mm)	Thick (mm)	Wt (g)
21	112	VII	5	hammerstone	battered	complete	quartzite	buff	193	140	81	22.71
21	113	II	1	hammerstone	battered	complete	quartzite	brown	72.5	61.5	40.6	226.9
21	113	IV	1	frag		internal frag	quartzite	brown	25.4	20.7	3.3	1.7
21	113	IV	2	concretion		split	chert	cream	44.5	34.9	26	24.2
21	113	IV	3	hammerstone	battered	complete	quartzite	buff-tan	83.3	78	42	367
21	113	VII	1	hammerstone	battered	complete	quartzite	buff-tan	78.8	55.3	49.1	245
21	113	VIII	1	hammerstone	battered	complete	quartzite	tan-brown	121.6	83.7	42.9	673.8
21	113	VIII	2	s-n projectile point	indented base	complete	Chert	white	33.68	13.78	3.44	1.1

V DEBITAGE

The study of debitage has led archaeologists down a tortuous path and has assumed many forms. Initially, archaeologists discarded debitage, considering it to have limited interpretive value. Through experimentation by those involved in tool replication, awareness of the potential informational value of debitage increased (Crabtree 1966). Despite the fact that we have known for some time that lithic debitage might add considerably to the interpretation of lithic assemblages, progress in debitage analysis has taken place very slowly. Expectedly, different kinds of analyses have emerged as archaeologists have became more aware, both in terms of the possibilities debitage offers for providing information about their assemblages, and as they have become more aware of the problems inherent in the analyses performed. Andrefsky (2001) differentiates three prevailing kinds of debitage analysis: aggregate, typological, and attribute.

Aggregate analysis, or mass analysis, has assumed considerable importance as a means of dealing with very large samples. Mass analysis typically involves separating debitage into weight and/or size classes, frequently using nested sorting screens with incremental grid sizes. Development of mass analysis to deal with the immense quantities of lithic debitage acquired during work at the Knife River Quarries provides an early and carefully considered example (Ahler 1986; 1989; Ahler and Christensen 1983). Mass analytical techniques probably exhibit their greatest utility when comparing two or more discrete or analytically isolable assemblages, for example, debitage from a quarry location as contrasted with a habitation site or a kill/ processing area. Mixed assemblages present a particular problem for mass analysis (Ahler 1989). Mass analysis has certain advantages in that it tends to reduce observer error and depends little on subjective observations. Mass analysis continues as an important mechanism for dealing with very large quantities of lithic debris, particularly under constraints imposed by limited time and/or financial support for such analysis.

Following Andrefsky (2001), typological analysis classifies individual flakes based on criteria of interest. Modern knappers, applying their experience in manufacturing stone tools, have classified flaking debris on the basis of reduction sequence (primary decortication flake, secondary decortication flake, bifacial reduction flake, etc.), type of hammer utilized (hard/soft), the nature of the applied force (direct percussion, indirect percussion, pressure, bipolar, etc.), or other perceived technological criteria. While recognizing the importance of flake typologies for dealing with specific issues of lithic production, Sullivan and Rozen (1985) also point to the frequently subjective nature of such typologies. Not all flakes removed from bifacial cores exhibit the attributes usually attributed to bifacial thinning flakes and some flakes removed from other cores may display those traits. Size alone may determine whether the analyst classifies a specimen as a pressure flake rather than a percussion flake. Such analyses have rarely succeeded in validating the relationship between the debitage type and the interpretation of the technology or inferred use (Andrefsky 2001).

Attribute analysis has assumed increased prominence in the last two decades. While not new, attribute analysis of debitage received a shot in the arm from a controversial presentation by Sullivan and Rozen (1985). They argued that debitage analysis should stress objectivity and replicability by using criteria not subject to interpretation. By utilizing a key with three variables, each variable with two dimensions, they proposed to move debitage analysis into a more objective realm.

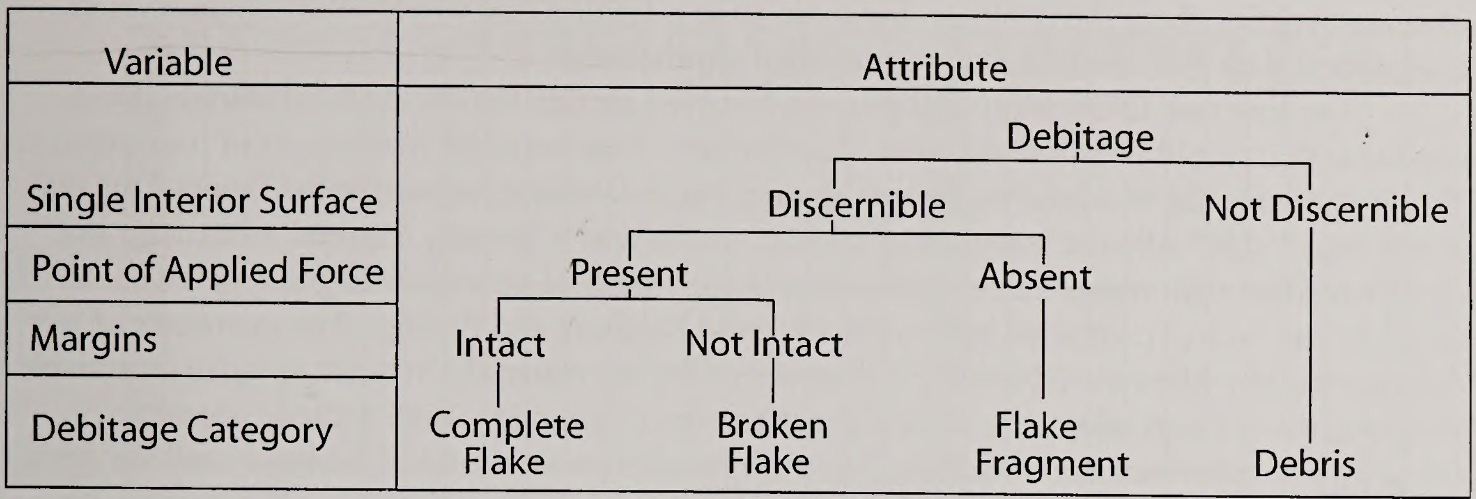


Figure 17. Sullivan and Rozen Typology (SRT) Key for Debitage Analysis (after Sullivan and Rozen (1985:758-759, Figure 2).

The Sullivan and Rozen typology (SRT) argued for use of a key with variables and attributes as follows: single interior surface (yes-no), point of applied force (present-absent), margins (intact-not intact) (presented diagrammatically in Figure 17). Analyzing debitage following the key identifies four debitage "categories": debris, flake fragments, broken flakes, and complete flakes. The original paper (Sullivan and Rozen 1985) and the comments (Amick and Mauldin 1989a; Ensor and Roemer 1989) and rejoinders (Rozen and Sullivan 1989a; Rozen and Sullivan 1989b) it almost immediately precipitated, quickly spurred a flurry of activity focused on critically examining the assumptions and results underlying the SRT (Amick and Mauldin 1989b). These included a number of experimental studies intended to assess the replicability and validity of SRT (Prentiss 1998:646-637; Prentiss 2001). Among other issues, ingenious experimental studies have examined the effects on debitage assemblages of trampling (Prentiss and Romanski 1989); flake size, particularly in relation to raw material type (Prentiss 1998); percussor type, and platform preparation parameters, among others (Prentiss 2001).

SRT has endured, but not without criticism and some proposed modification. Prentiss (2001:148, 171) has argued that the addition of four size classes—small (0.64 - 4.0 cm^2), medium (4.0 - 16.0 cm^2), large (16.0 - 64.0 cm^2), and extra large (>64.0 cm^2)—significantly improves the validity of SRT . He has labeled this modification to the Sullivan and Rozen typology the MSRT.

In the process of conducting our analysis of the debitage excavated from the berms of the quarry pits at Camp Baker, we considered each of the three analytical approaches discussed by Andrefsky (2001). Initial examination of the quarry site revealed debitage exposed by the road cut and eroding from the berms on the down slope edges of the quarry pits. Superficial observation at that time indicated the presence of a wide range of cultural debris including non-chert quarry debris, tested chert blocks, cores, core reduction debris, and a relatively high frequency of subsequent reduction debitage seemingly suggesting the production of bifacial cores and subsequent bifacial reduction stages (Callahan 1979). If we adhered exclusively to one of the three analytical approaches to the debitage, much of the information relative to

those early observations could disappear in the analysis. We determined to gather a wide range of characteristics about the debitage, but to do so in a fashion that would allow some level of comparison with any one of the three analytical approaches.

The first task in the analytical process involved getting the excavated materials into a condition that would permit reasonable observations. That required washing all of the debitage. Two individuals did all of the washing with one, Justin Garrison, assuming the brunt of the task. A silty clay "skin" adhered tenaciously to most specimens. Cleaning required immersion in a container filled with warm water laced with a healthy dash of an industrial grade detergent to emulsify the "skin," combined with relatively mild brushing and rinsing. The quantities of wet debitage rapidly filled the laboratory with racks of drying material. In order to make reasonable progress, the workers adopted a schedule that had them removing dried debitage from racks filled with the previous day's washing into trays, washing a new load of debitage until the drying racks had filled, and then size sorting and counting the debitage on the trays. Typically, 1 hour of washing required 3-5 hours of size sorting and counting.

In an attempt to avoid edge damage to the specimens, and to circumvent the "hypotenuse problem" whereby some smaller specimens hang up in sorting screens and some long, narrow items slip through, we decided to use a template to sort the debitage. The template consisted of 1 cm squares that increased in 1 cm increments from 1 to 15 (Figure 18). To determine size class, the analyst identified the smallest square capable of containing the largest possible orientation of the entire specimen. Size classing included all cores and debitage. Table 5 provides actual and relative frequencies of size classes for Pit 4 by unit and level and for Pit 21, Unit 112, by level.

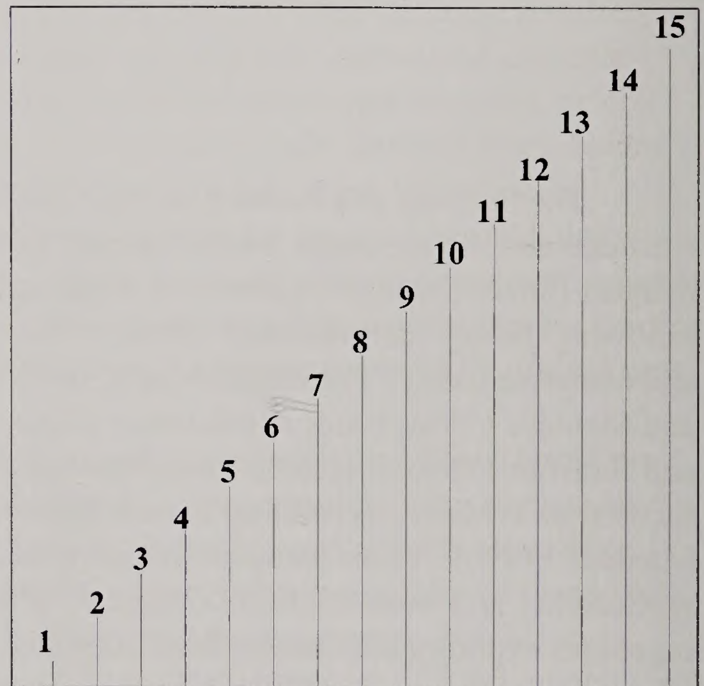


Figure 18. Debitage size sorting template (cm).

Figure 19 contrasts the relative frequency for size classes by pit, collapsing units and levels. Nearly identical size class distributions prevail for the two pits. In total, the two test excavations resulted in the collection of 12,074 pieces including cores and debitage. Size classes 2, 3, and 4 account for 71.6% and 72.2% of Pits 4 and 21 respectively. Including size class 5 increases the relative frequencies to 82.4% and 82.3%. Upon attempting to evaluate the probability of such a distribution occurring by chance, the large number of size classes and the small number of items in the larger size classes resulted in expected frequencies of occurrence less than 5 in one or more cells. Merging size classes to approximate the four classes employed by Prentiss (2001:148, 171) allowed evaluation with the chi-square statistic. At 3 df a chi-square value of 20.5181 rejects the null hypothesis (random association) at the 0.001 level of confidence. Figure 20 graphs the relative frequencies of the condensed debitage size classes. While interesting, the size class data alone can only suggest that whatever activity transpired at the Camp Baker Quarry, it produced similar relative frequencies of debitage sizes in Pits 4 and 21.

Table 5. Distribution of Debitage Size Class from Excavation of Pit 4, all units, and Pit 21, Unit 112.

Pit	Unit	Level	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15	Grand Total
4	18	VI		1		2													3
4	18	VII		5	10	1	1												17
4	18	VIII		3	4	5	2	1	1		1								17
4	18	IX		4	7	2	2				1								16
4	18	X	1	5	5	5	3	3				1							23
4	19	I		2	7		1												10
4	19	II	1	70	23	21	10	2	3	1									131
4	19	III			67	38	23	18	10	2	1								159
4	19	IV		21	96	74	39	26	20	12	1	0						1	290
4	19	V	4	5	7	1	1	3	1	1	1					1		1	26
4	19	VI			3		1	1		1									6
4	20	I		4	6	3	6	2	1	1	1								24
4	20	II		3	4	3	3	3	2	2									20
4	20	III	22	205	120	89	42	30	15	10	10	1							544
4	20	IV		29							4	1	2	1					37
4	21	IV	3	31	29	25	23	13	6	1	4	1						0	136
Grand Total			31	388	388	269	157	102	59	31	24	4	2	1		1		2	1459
%4			2.12%	26.59%	26.59%	18.44%	10.76%	6.99%	4.04%	2.12%	1.64%	0.27%	0.14%	0.07%	0.00%	0.07%	0.00%	0.14%	
Pit	Unit	Level	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15	Grand Total
21	112	I		11	8	27	20	15	7	3	1	1			1				94
21	112	II		19	78	70	50	30	10	12	4	1							274
21	112	III		14	53	42	24	17	6	2		1	1				0	0	160
21	112	IV	4	26	78	66	34	41	21	6	4	4	1				1	1	287
21	112	V	2	72	93	74	43	28	16	15	4	3	0						350
21	112	VI	17	131	162	103	72	31	37	19	6	3	4	2			0		587
21	112	VII	109	717	750	348	241	159	102	48	26	14	1	3	1				2519
21	112	VIII	91	586	398	211	98	48	19	13	4	4		1					1473
21	112	IX	54	374	187	83	30	14	5	1	1	1		1		1			752
Grand Total			277	1950	1807	1024	612	383	223	119	50	32	7	7	2	1	1	1	6496
%21			4.26%	30.02%	27.82%	15.76%	9.42%	5.90%	3.43%	1.83%	0.77%	0.49%	0.11%	0.11%	0.03%	0.02%	0.02%	0.02%	

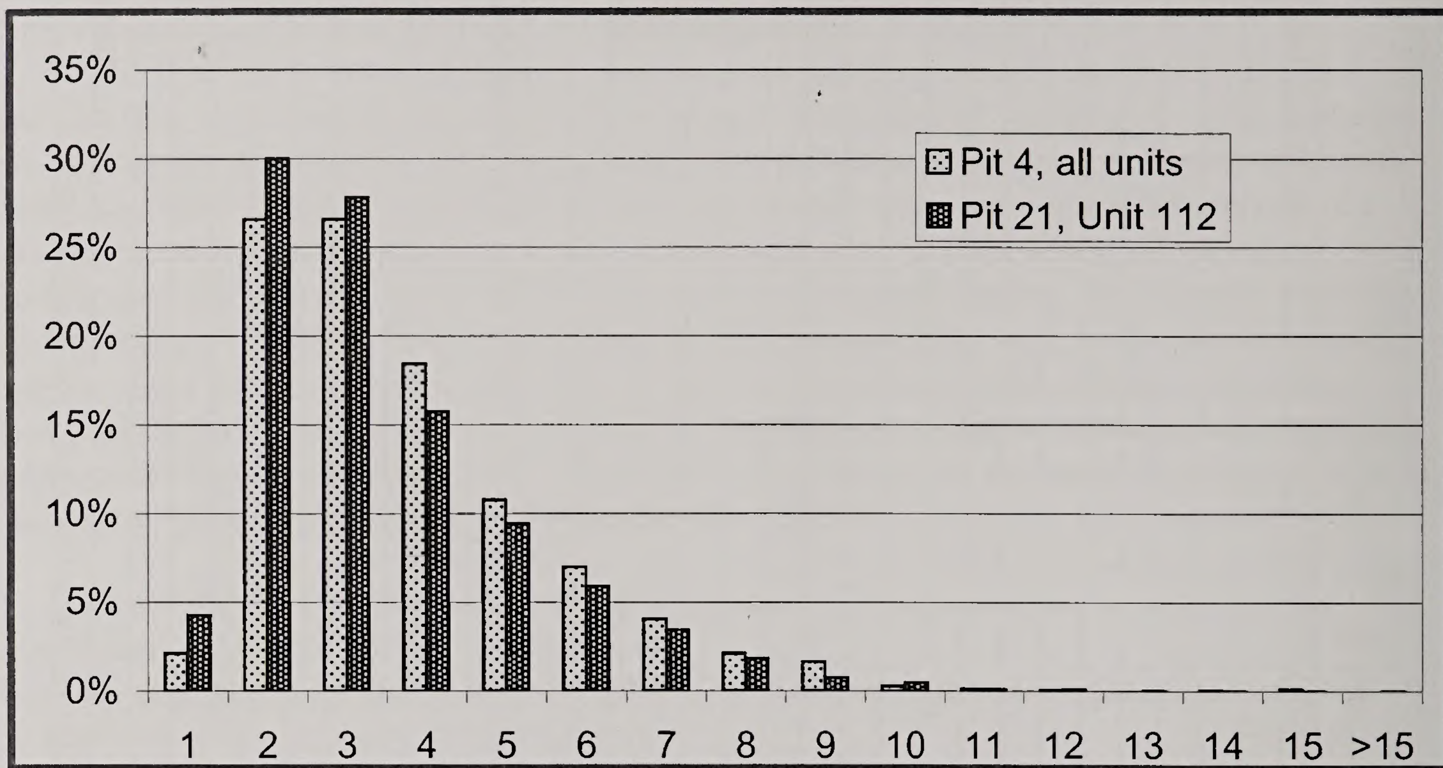


Figure 19. Relative frequency of debitage size classes by pit.

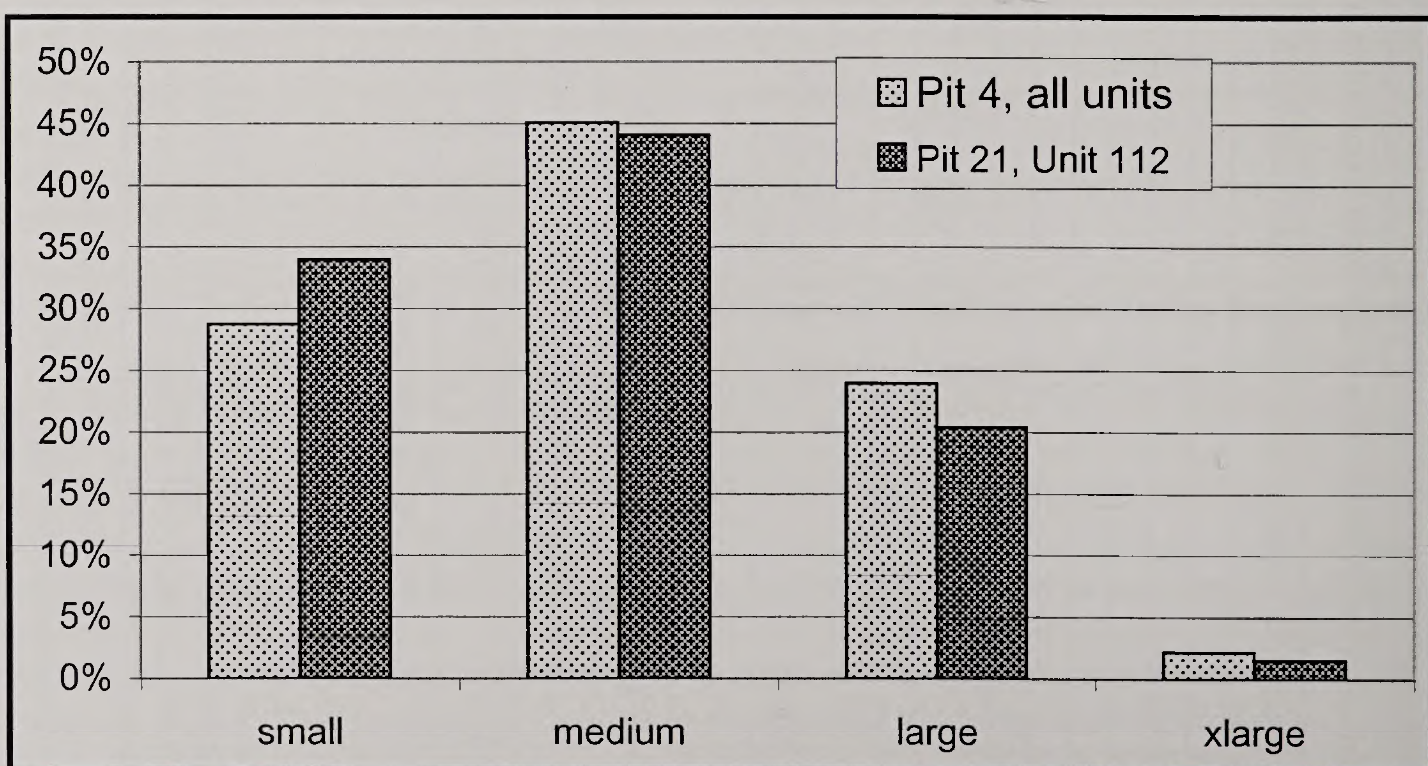


Figure 20. Relative frequency of merged size classes (after Prentiss 2001) by pit.

Using size as a starting point, subsequent debitage analysis essentially followed the SRT with some minor variations and the addition of platform types. Figure 21 presents the debitage analysis decision tree used for this project. The first decision level required sorting items into cores, flakes with proximal ends, and fragments. The next decision depended on a dichotomous choice as to whether the piece contained greater than 5.0% cortex or not. From there, the decisions became more involved. Cores were classified as to whether or not they were complete or fragmentary. Fragments were separated into flake fragments, chunks, and shatter. As in the SRT, flake fragments exhibit an internal flake surface that permits orientation of the flake in relation to the direction of applied force despite the fact that no platform remains. Chunks and shatter cannot be oriented in relation to the direction of applied force. Ultimately, chunks and shatter were combined as their separation depended primarily on size. Because of the uniformity of the analyzed samples from all units of Pit 4 and Units 111 and 112 of Pit 21, we elected to forego detailed analysis of Unit 113 from Pit 21. Future references to Pit 21 debitage are based on the analyzed sample from Units 111 and 112 exclusively.

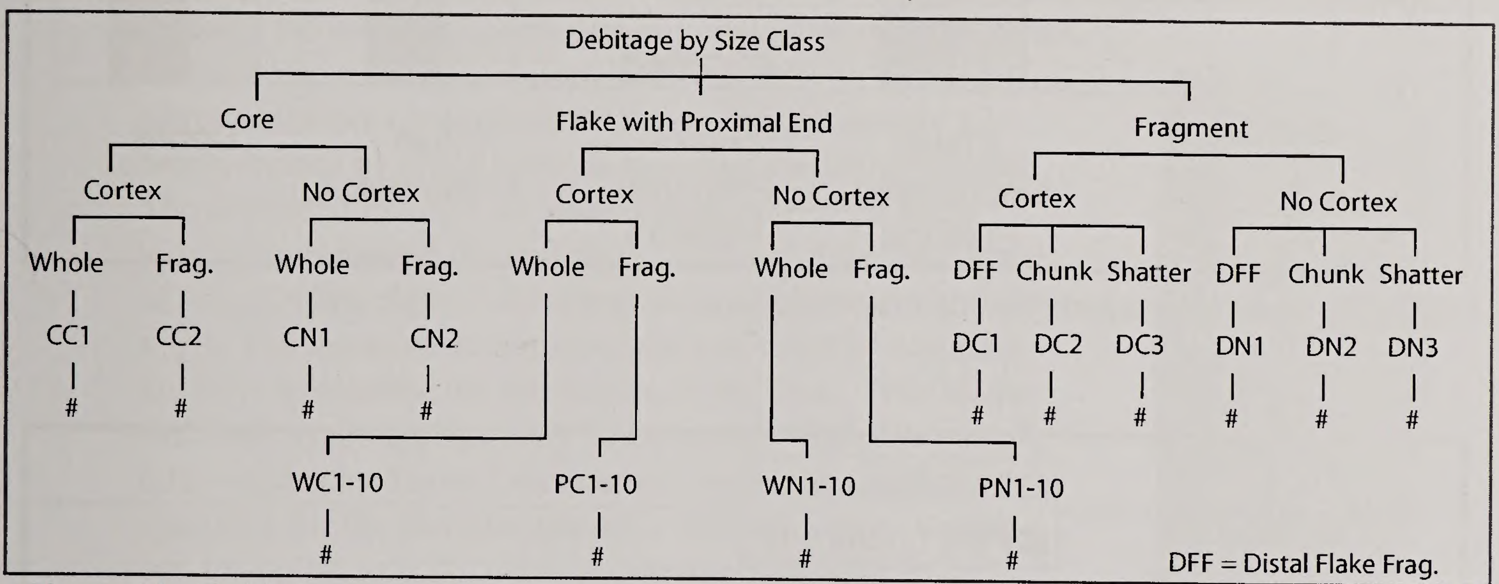


Figure 21. Debitage analysis decision tree.

At the maximum level of expansion, including all core elements, flakes with proximal ends, flake fragments, and debris, the possibility exists for 50 debitage types; flakes with proximal ends potentially encompass 40 types. In order to understand the debitage, it has become necessary to collapse certain of the divisions created in the initial analysis. Figure 22 presents the frequency of debris essentially consistent with the categories of the SRT, but with the added distinction of unprepared vs. prepared platform flakes. Although complete flakes outnumber flake fragments, the combined categories of flake fragments and debris dominate the assemblage.

A Cores

Analysts commonly separate cores from debitage. Because the work conducted at the Camp Baker Quarry emphasized material abandoned after acquisition and subsequent modification, we elected to include cores as part of the debitage assemblage. Cores consist of chert blocks and/or nodules with evidence of flake removal but no additional modification. Identifiable cores proved extremely rare; Pit 4 yielded 14 cores, or approximately 0.8% of analyzed debitage; Pit 21 contained 41 cores, about 0.5%. Figure 23 presents the relative frequency of core types by pit. Combining cortical cores (complete and fragmentary) into one group and noncortical cores into another results

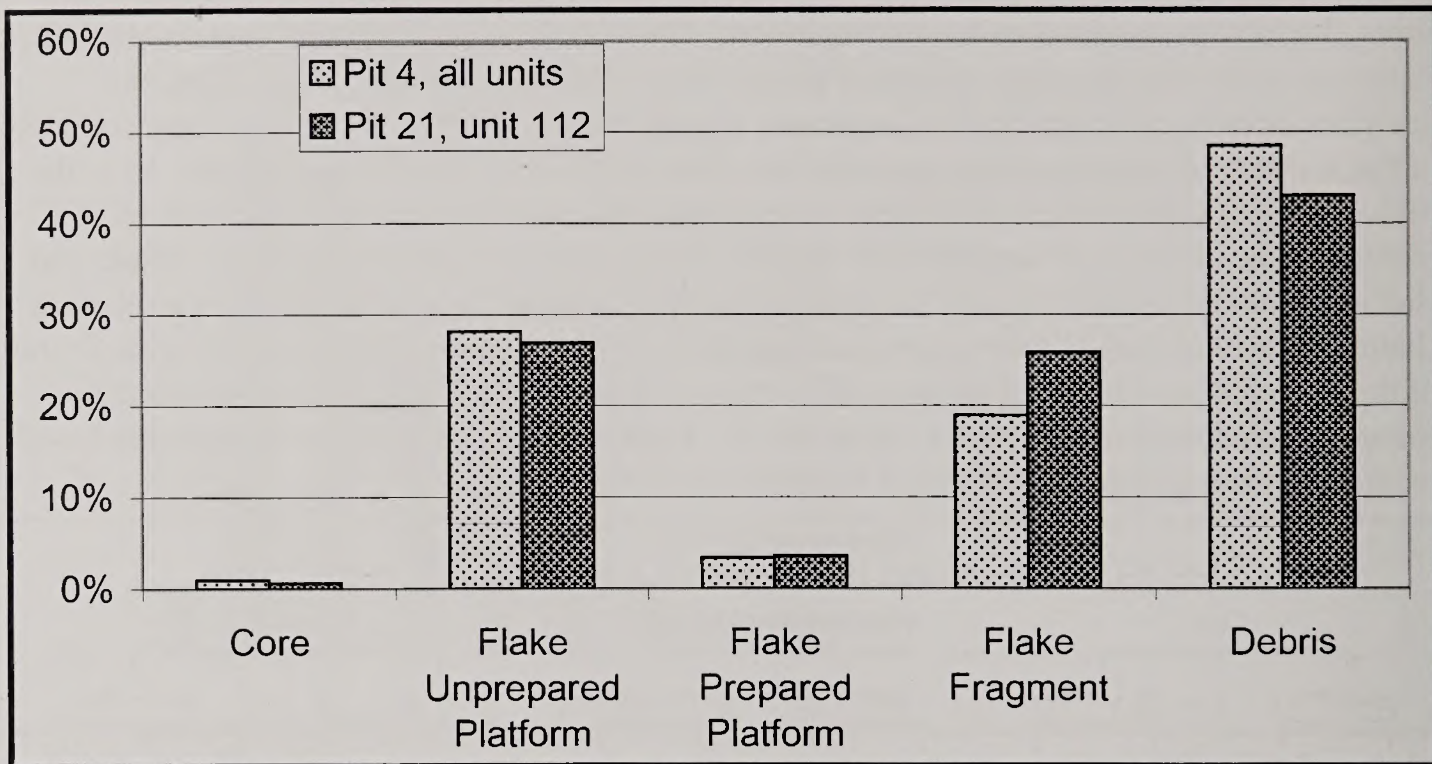


Figure 22. Relative frequency of debitage categories by pit.

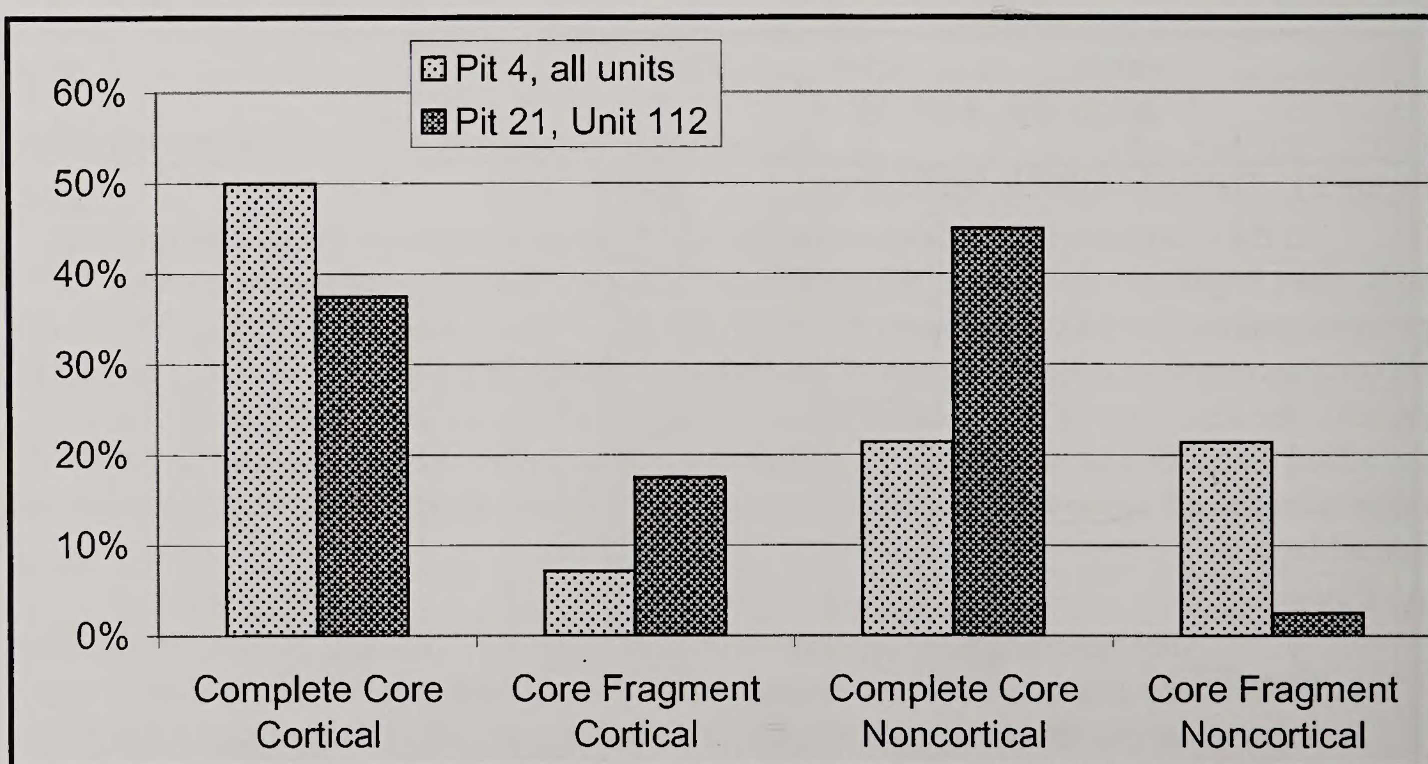


Figure 23. Relative frequency of core categories by pit.

in cortical cores representing 57% and 50% of cores from Pit 4 and Pit 21 respectively. Attempting to run the chi-square statistic results in 3 of 8 cells with expected values less than 5.0, thus invalidating use of the statistic. The extremely small sample size for cores probably accounts for apparent variation in the complete vs. fragmentary and cortical vs. noncortical core distribution in the two pits. Most of the cores exhibit no preparation, or very little preparation, and no clear reduction strategy emerges from the flaking patterns. Though other alternatives exist, the low frequency of cores may suggest transport of high quality cores from the immediate quarry pit to other locations for subsequent use.

A single, nearly symmetrical, cylindrical, prismatic blade core stands out from the remainder of the assemblage (Figure 24). The specimen comes from Pit 21, Unit 113, Level V (Stratum 2). Maximum physical dimensions are as follows: length—72.36 mm, width—28.20 mm, thickness—23.48 mm, weight—35.3 g. The specimen appears nearly exhausted, and the knapper either attempted to rejuvenate the surface of applied force before discard or an accidental perverse fracture removed the original platform surface. No evidence exists of additional platform preparation and no clear-cut negative Hertzian cones remain on the lateral edges of the proximal (platform) end. Approximately 12 facets created by blade removal surround the circumference. The distal end exhibits no modification other than blade terminations around the periphery. The raw material consists of a highly brecciated, variegated colored chert with abundant vugs. The inconsistent nature of the raw material certainly did little to enhance the production of the core. True blades and blade cores appear rarely in Montana. The presence of a few blades by themselves does not represent a sufficient condition for the identification of a blade industry. During any knapping episode, a few accidental blade-like flakes may result. The presence of blades in association with blade cores often suffices to suggest deliberate production of blades. The debitage analysis identified 17 very nice, but possibly fortuitous, blades or flake-blades, all from Pit 21, Unit 112, Levels VII and VIII (bottom of Stratum 2 or top of Stratum 3). The existence of a single prismatic blade core and a few possible blades contributes little to the issue, but must receive consideration with future work in the Smith River area.

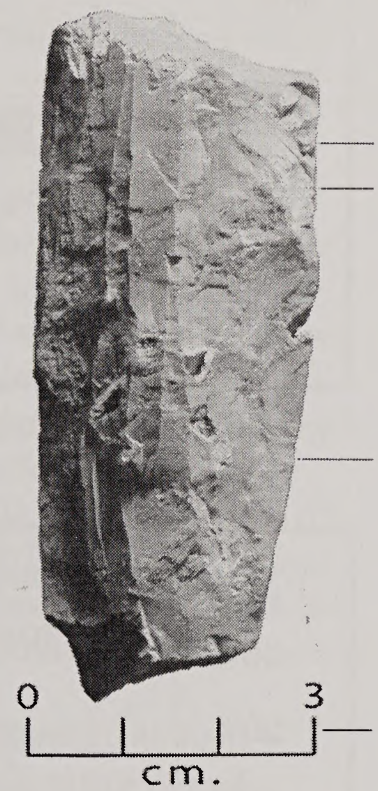


Figure 24. Prismatic blade core.

B Flakes, Distal Flake Fragments, and Debris

Flakes that retain the proximal end represent the most analytically interesting and diverse portion of the debitage assemblage. As with other debitage, the first dichotomous division separated flakes into cortical (>5%) and non-cortical. The second division evaluated whether the flake retained its distal and/or lateral margins. (Are the margins sufficiently intact to allow approximations of the unbroken flake dimensions?) If so, the flake fell into the complete category; if not, into the fragmentary category. Once separated as to completeness, the type of platform was determined for each specimen. Ultimately, the typology included ten platform types as detailed in Table 6. As with most

other categories of debitage, platform types demonstrate remarkable consistency between pits, supporting the idea that essentially similar lithic reduction practices produced the debitage contained in the berms of Pit 4 and Pit 21. This holds for relative frequencies of all platform types when compared by pit (Figure 25) and for the comparison of relative frequencies of complete vs. broken flakes (Figure 26).

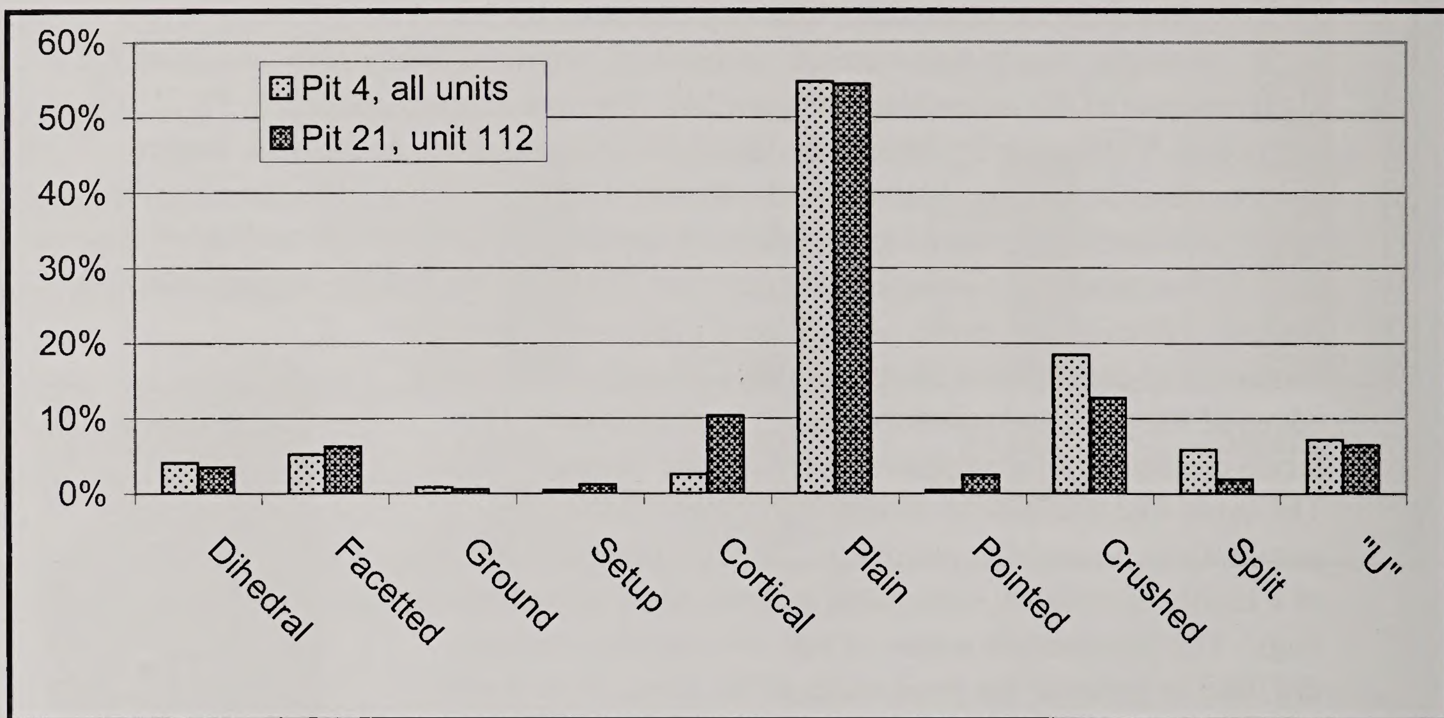


Figure 25. Relative frequency of platform types by pit.

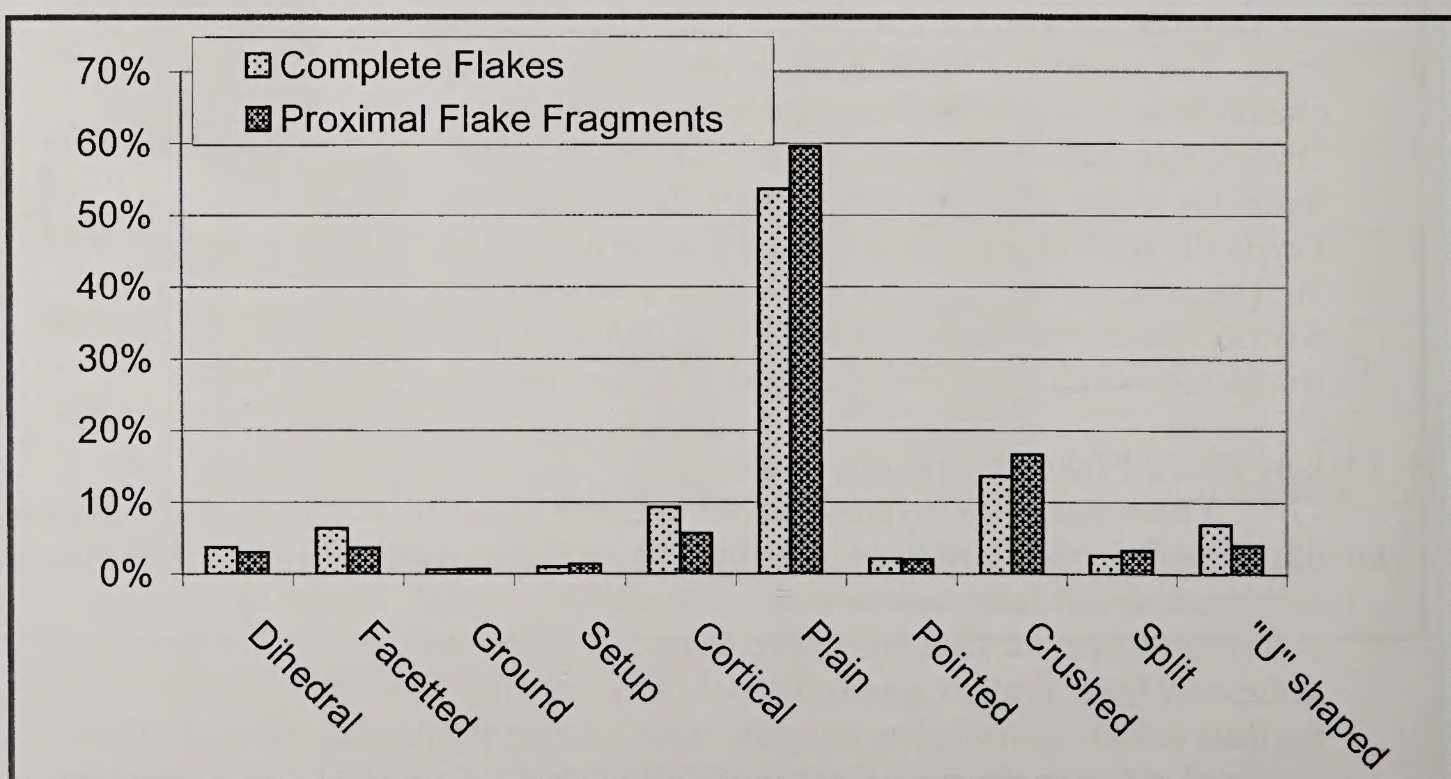


Figure 26. Relative frequency of platform type for complete flakes vs. proximal fragments.

Table 6. Description of platform types identified in debitage analysis.

Platform Type	Nature of surface of applied force
1. Cortical	Cortex, with no additional modification.
2. Plain	Planar, no additional visible modification.
3. Dihedral	Prepared by two flake removals.
4. Facetted	Prepared by more than two flake removals.
5. Pointed	Planar, pointed appearance probably created by shape of percussor.
6. Crushed	Acute, with no discernable preparation.
7. Split	Planar, but split vertically through bulb of percussion.
8. Ground	Prepared by grinding to change angle or enlarge surface.
9. "U" shaped	Ventral bulb directly behind negative bulb from previous flake removal, surface usually planar.
10. Setup	Planar or prepared, dorsal surface of flake exhibits small flakes removed to rejuvenate or "trim" the platform, mostly planar.

Recognizable differences in debitage between quarry pits proved difficult to assess. Beyond partitioning the data by quarry pit, stratigraphy provided the only other physical mechanism for segregation of the debitage assemblage. In Pit 4, the shallow depth of deposits, and the fact that the excavated arbitrary levels invariably crosscut two or more strata, precluded any attempt to assess the possibility of differential debitage production between strata. The depth of deposits and the relatively level nature of the natural stratigraphy in Pit 21 allowed for limited testing for differential debitage production by stratum. In Pit 21, Unit 112, arbitrary levels I, II, III, and IV includes all of Stratum Ia and Ib and very little of the upper portion of Stratum 2. Levels V, VI and VII comprise all of Stratum 2 and part of Stratum 3. Levels VIII and IX incorporate the remainder of Stratum 3, Stratum 4, and the excavated portion of Stratum 5. (see Figure 12 and Figure 13).

Sullivan and Rozen (1985:769) argue that debitage assemblages with higher percentages of flake fragments and broken flakes should result from biface or tool manufacture, while high proportions of complete flakes and debris likely coincide with core reduction. Evaluation of the proposition that differential debitage production occurred in different strata began by examining those categories of debitage addressed by Sullivan and Rozen. A chi-square value of 102.23 at 6 df suggests a strong association between stratum and debitage category. Examination of the relative frequencies charted in Figure 27 reveals an inverse relationship between complete flakes vs. distal flake fragments and debris. Complete flakes decrease with depth and both distal flake fragments and debris increase with depth. We might take the greater frequency of complete flakes in the upper levels as indicative of a greater emphasis on core reduction than in lower levels, but concomitant lower frequencies of both distal flake fragments and debris in the upper levels contradict that conclusion. In the Sullivan and Rozen model, increased frequencies of debris should accompany increased frequencies of complete

flakes. The statement of the relationship between debitage classes and lithic reduction activity made by Sullivan and Rozen posits high proportions of certain lithic categories will associate with particular activities; it does not address the issue of what constitutes a high proportion. It appears likely that debris collected from a site, or sites, strongly focused on a limited range of narrowly associated activities, such as extracting and preparing stone for transport and subsequent modification, may not yield data amenable to separation using the kinds of distinctions proposed by Sullivan and Rozen. While clear-cut trends exist, a reasoned explanation for the trends is less obvious.

Information from size classes may provide another dimension to the issue of whether or not evidence exists that supports the possibility of different kinds of lithic reduction activities in different strata at the Camp Baker Quarry. Again, merging the 1 cm^2 size classes from our initial analysis to approximate the four size grades proposed by Prentiss (2001), we determined the size grades for the four SRT debitage types (complete flakes, broken flakes, flake fragments and debris). When placed in a 3 x 4 table (size grade/stratum) the resultant chi-square of 726.89 at 6df strongly supports the notion of a nonrandom association between size grade and stratum. Because the percentages of small size grade debris occurs in such low percentages, Stratum 1 dominates the other strata in percentages of the three larger size grades. Neither debitage categories nor size grade answers the question of what difference in activity produced the disparity in vertical distribution. A higher percentage of complete flakes and lower percentages of flake fragments and debris prevail in the upper stratum. Seemingly, in direct association with the observation about differentials in debitage categories, the smallest debitage size grade occurs in lowest frequencies in the upper stratum. This trend prevails, with only minor discrepancies, whether comparing individual size grades against debitage type by stratum, or individual debitage types against size grades by stratum. Consistently, Stratum 1 has a higher frequency of complete flakes than the other strata, and, at the same time, the debitage size grades from Stratum 1 are larger (Figure 28).

The results directly contradict the notion that resource depletion encouraged conservation of raw material. Speculation about the factors responsible for the observed change in debitage production could cover a wide spectrum of ideas. These might involve physical attributes of the quarry itself, such as differences in raw material quality with depth or exposure. Site formation processes, such as differential trampling or downward movement and concentration of small items at deeper levels, might account for the observation (doubtful given the nature of the sediments). A change in lithic reduction strategy in response to cultural or natural variables might provide fruitful approaches. With those questions in mind, additional excavation in Pit 21 and other quarry pits might serve to reveal part of the nature of the change in debitage distribution or it might completely alter the perception provided by these results.

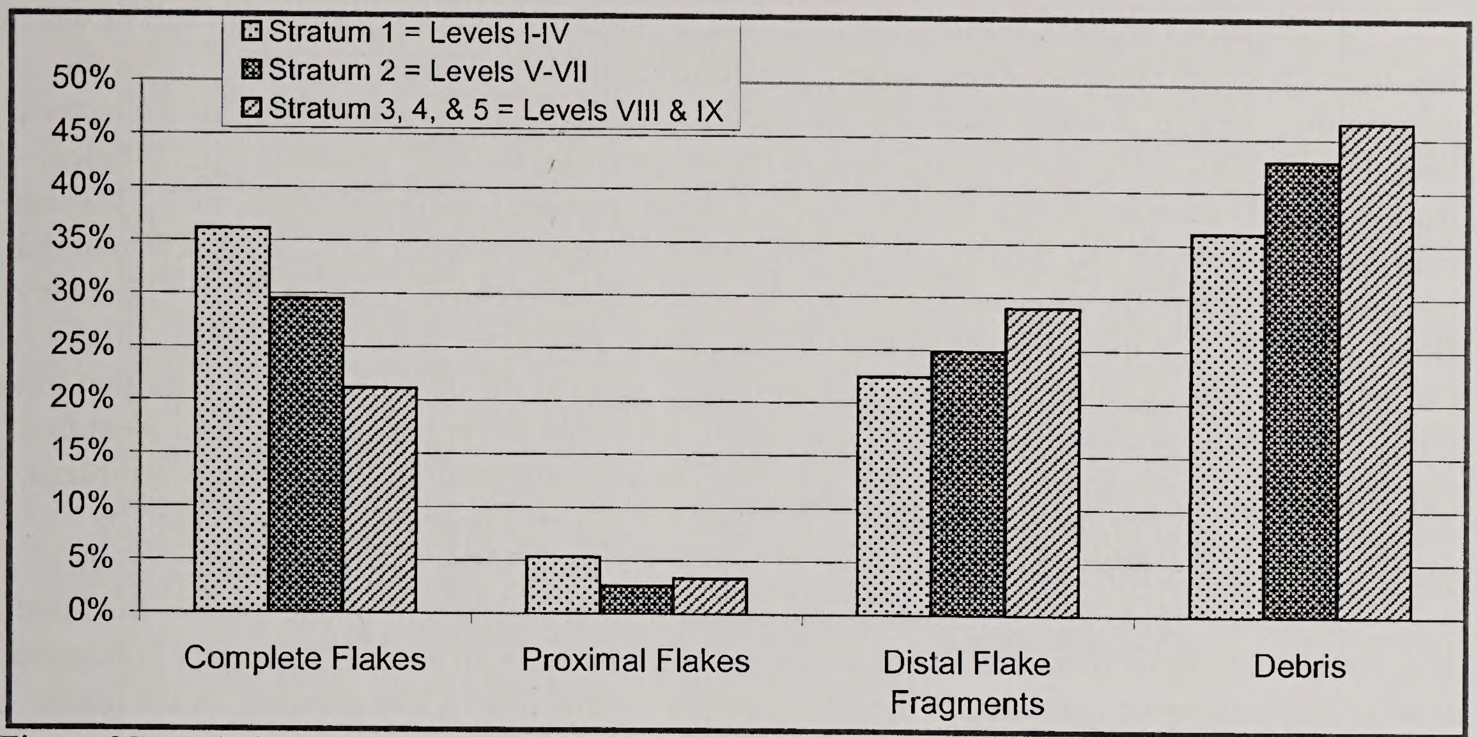


Figure 27. Relative frequencies of SRT debitage categories for Pit 21, Unit 112 by stratum.

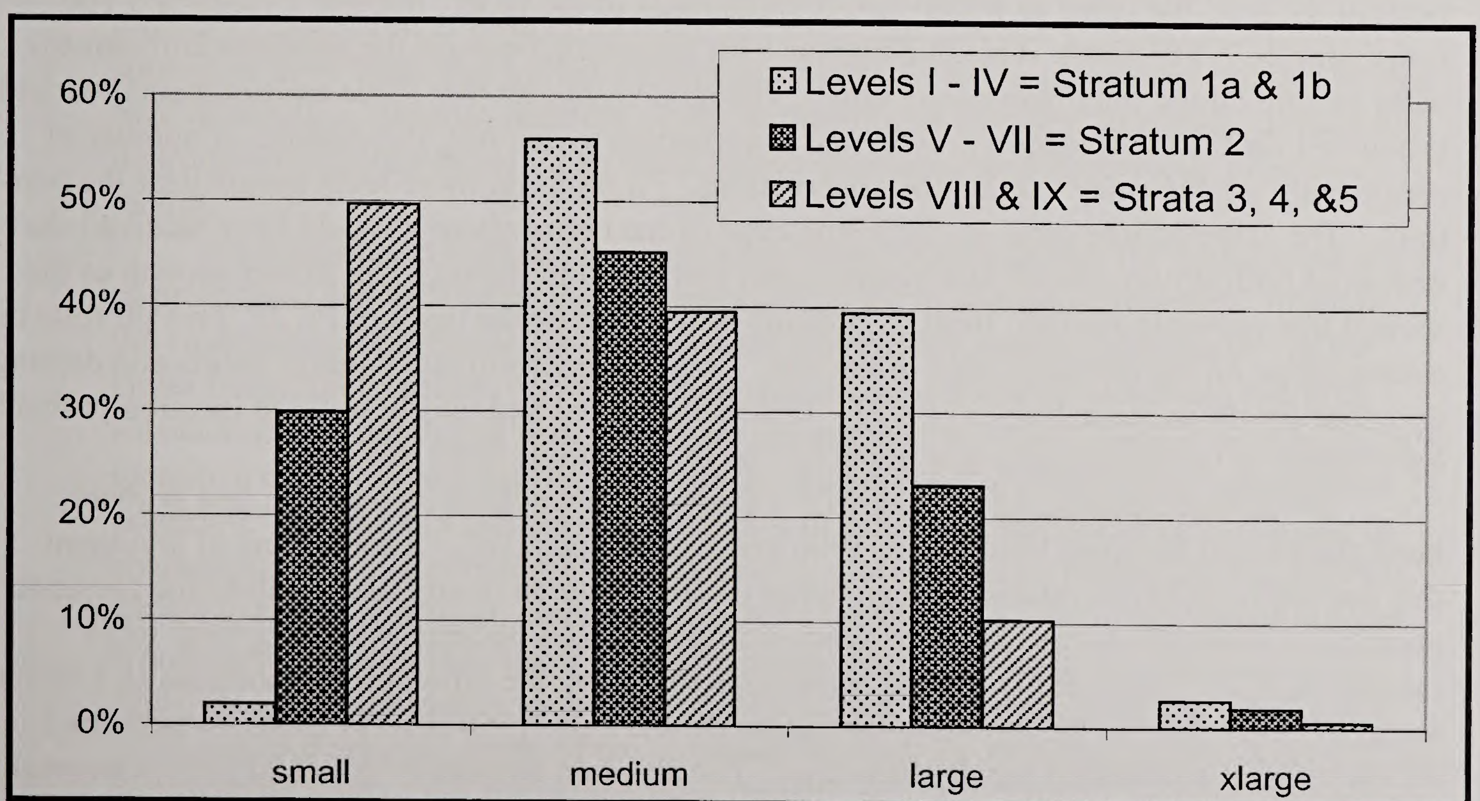


Figure 28. Relative frequency of debitage size grades from Pit 21, Unit 112 by stratum.

VI CHRONOLOGY

Excavations in 2001 disclosed only minute quantities of bone and charcoal—all of which was from uncertain contexts. These factors precluded radiocarbon dating as a mechanism for determining site age. A single small side-notched projectile point, typical of the Late Prehistoric Period (A.D. 200–1600) of the Northwestern Plains, provides the only potential chronological marker directly associated with the site. Larry Lahren (personal communication, July 2003) has expressed the opinion that the Doggett Quarry provided approximately 50% of the raw material used to manufacture the stone artifacts from the Anzick Clovis Burial (Lahren 2001; Lahren and Bonnichsen 1974; Wilkie, Flenniken and Ozbun 1991). However, at the time Lahren initially examined the Anzick stone tools, the Doggett Quarry seemed the only likely source for that lithic type. Since then, an extensive series of quarries in the Smith River corridor has been identified and any or all of these quarries may have provided the raw material for the Anzick assemblage. Whether continuous or sporadic in nature, the Smith River area probably has been used by prehistoric foragers from Clovis times (ca. 11,000 B.P.) through the Late Prehistoric Period.

In an attempt to gain some additional chronological assessment of site use, we tried tree-ring counts. Using an increment borer, two cores were taken from among the largest Ponderosa Pine (*Pinus ponderosa*) growing in the site. Sample 1 came from a tree growing on the inside edge of the down slope berm of Pit 6. A tree growing near the crest of the berm of Pit 21 yielded the second core. In both instances, the trees should post-date the last use of the quarry pits, perhaps by a substantial amount of time. From the cambium layer to the heart of the tree measured 277 mm for sample 1 and 175 mm for sample 2. Neither sample included the precise heart of the tree, but came to within two or three rings of the heart. Sample 1 contained 100 rings, sample 2, 183 rings. This finding was a bit surprising because the shortest cambium-to-heart sample turned out dramatically older. The results suggest that some environmental variable accounted for the difference in growth rate documented by the ring increments. A number of contextual variables may explain the observations. Pit 6 lies on more level terrain near the two-track. The sampled tree grew on the inside edge of the berm where it would have received the benefit of both slower run off and puddle water entrapped in the pit. The slower growth of the second tree probably resulted from its position at the crest of the berm of Pit 21. This pit rests on a steep slope on the downhill edge of the site. Largely unconsolidated quarry debris and debitage compose the down slope berm of Pit 21. This well-drained and poorly watered location probably contributed to the narrow ring spacing observed in the sample from this tree.

From these results, we can say with some confidence that Pits 6 and 21 had probably been abandoned for some time before 1900 and 1815 respectively. Another line of argument that has applicability to establishing an upper limiting date on quarry use involves the presence/absence of items of European origin. Once European goods became available, stone tools rapidly declined in popularity. In the Northwestern Plains, the influx probably began as a trickle about the same time as the arrival of the horse, around A.D. 1750 (Ewers 1955), or perhaps a bit earlier, and accelerated rapidly thereafter. The absolute absence of goods of European origin from excavated contexts suggests, but cannot document, abandonment before 1800.

VII SOURCING STUDIES

A Lithic Characterization Studies

The acquisition of raw material for stone tool manufacture played an important role in the activities of people dependent on those tools for their day-to-day survival. A number of possible strategies exist for procurement of suitable raw materials. In some instances, such as long-distance acquisition of exotic resources, explanation depends on organizational parameters beyond normal, day-to-day, subsistence organization. Scholars have attributed the acquisition of Yellowstone Cliff Obsidian from the Yellowstone National Park area by Hopewell people of the Midwest (~2400 km or ~1500 mi. straight line) to specialized task group(s) focused on a particularly valued resource or to long-distance inter-societal trade (Griffin, Gordus and Wright 1969; Hatch, et al. 1990). These attributions have remained topics of controversy (Cowan, Hughes and Wiant 2003). At the other end of the procurement spectrum, Binford (1979) observes that Nunamiut subsistence organization tends to incorporate lithic procurement in concert with other activities. Recognition that lithic procurement probably occurs along a continuum, with one extreme expressed by the "embedded" nature of Nunamiut lithic procurement and another extreme by more dedicated or "disembedded" (Seeman 1994) resource specific procurement, has generated substantial discussion (cf. (Gould and Saggers 1985; Binford and Stone 1985; Ricklis and Cox 1993; Seeman 1994)).

In part, the difficulty emerges from the nature of archaeology itself. The archaeologist may observe the distribution of discarded tools and production debris on the landscape, but that distribution says little without interpretation. Addressing the issue of whether the distribution of a resource results from logistical movement, activities of specialized task groups focused on acquiring a particular resource, from residential mobility, acquisition embedded in other activities that places a group in proximity to a source, or upon trade that moves goods from their source through intermediaries to their final destination, depends mightily on the archaeologist's powers to explain differential distribution of goods based on an often poorly developed and imperfectly preserved record.

Attempting to explain how the Camp Baker Quarry fit into the mobility patterns of prehistoric Native Americans must necessarily await additional research. Elsewhere, the coalescence of different lines of research has yielded substantial rewards. In the Great Basin, for example, use of obsidian and andesite/dacite as toolstones has both substantial time depth and widespread use geographically. Geochemical techniques have identified many of the Great Basin obsidian sources (Hughes 1989) with considerable precision. Similar, but less extensive, studies of other volcanic rocks have resulted in characterization of a number of andesite/dacite sources (Jones, Bailey and Beck 1997). Added to this, Great Basin archaeologists have developed a functional projectile point typology that allows placement of certain point types into broad chronological slots. Thus, they have the ability to determine, with a high degree of reliability, the age of a particular tool and the source of the toolstone selected for its manufacture. Knowing the approximate time of use for certain tools (mostly projectile points), and the source(s) of the toolstones used in their manufacture allowed Jones et al. (Jones, et al. 2003) to posit five Paleoarchaic "lithic conveyance zones" and, by extrapolation, say something about probable foraging territories during the Great Basin Paleoarchaic.

Undoubtedly, toolstone use and distribution has the potential to make similar contributions to the prehistory of the Northwestern Great Plains. A long record of work with obsidian sources and distribution has already made many contributions. Archaeologists commonly submit artifacts and debitage for XRF analysis to establish the probable source of the lithic raw material. In the not-too-distant future, we may look forward to interpretation of regional prehistoric lithic use patterns based on that work. Richard Hughes, Geochemical Research Laboratory, has successfully initiated characterization of fine-grained volcanic rock, in particular dacite, from known southwestern Montana sources with promising results (Baumler, et al. 2001). These studies anticipate providing similar information about source of origin and distribution as has emerged from obsidian studies. The ability to reliably identify lithic sources offers substantial potential to increase our understanding of prehistoric human activities. The attempts to characterize the Smith River chert sources and other sources in southwestern Montana represent an early effort in that process.

B LA-ICP-MS analysis of Selected Montana Chert Quarries

A visit to the Camp Baker Quarry, or any of the Smith River quarries, immediately impresses even the casual observer with the diversity of characteristics exhibited by the chert exposed on the surface. Macroscopic visual properties (after Luedtke 1992) of the cherts from the Camp Baker Quarry exhibit a wide range of variation in color, translucency, luster, texture and structure. All of the Smith River quarries contain chert with a wide range of visible characteristics. Simultaneous observation of several thousand pieces leaves the observer with the overall impression of a buff or tan color. Closer observation reveals color values that range from white to black, with occasional subtle hues in reds and blues and grays. Dark brown occurs as a minor, but prominent, color. Translucence of chert from these quarries ranges from opaque to clear, with opaque or very slightly translucent varieties being most common. Luster appears predominantly dull ("earthy") or satin, though waxy or shiny examples exist. Fractured surfaces most frequently display a smooth dull texture. Perhaps more variation exists in structure than color. Preliminary observations indicate a strong tendency to homogeneous structure, but banded, laminated, and mottled pieces exist in relatively high frequencies. Other common structural features include brecciation, resilicification, and dendritic inclusions.

The extensive overlap of macroscopic characteristics of chert from the Camp Baker Quarry with chert from many other sources, in southwestern Montana and elsewhere, seriously compromises our ability to attribute any chert to a particular source based on such characteristics. This led to the examination of instrumental techniques appropriate for more accurate characterization of individual, local, or regional sources. Characterization of cherts that permits source attribution has in some ways lagged behind that of igneous rocks, probably because of the complexities of dealing with the comparatively limited compositional variation possible in chert (Luedtke 1992:44-45 and Table 4.3). Luedtke (1992:110) points out that no one technique will work for all applications and advocates selecting "...the cheapest and simplest technique that will likely produce the results of suitable accuracy." After examining a number of alternative techniques, we focused on LA-ICP-MS because of its minimally destructive nature, relatively low cost, and very low detection limits.

The Archaeometry Laboratory at the University of Missouri Research Reactor, a National Science Foundation supported facility, requires that analyses they conduct have merit as research projects and requires the submission of peer-review of "mini-proposals" before they accept an undertaking. They viewed our proposal favorably and we collected *in situ* samples from unexcavated contexts in the bottom of Pit 21. Initially we submitted nine samples for LA-ICP-MS analysis. The results of that analysis (See Appendix A) encouraged us to submit a series of samples collected from two additional quarries in the Smith River area and from five quarries scattered about southeastern Montana (See Appendix B). Ultimately, analysis characterized a total of 54 samples from eight quarries. Four of the Camp Baker samples displayed multiple colors on the same specimen. Independent analysis of the distinct colors to assess possible chemical variation resulted in five additional analyses. This increased to 59 the total number of independent analyses conducted. As a result of the LA-ICP-MS analysis, the participants from Montana State University and the University of Missouri prepared a jointly authored paper for inclusion in a book on applications of LA-ICP-MS in archaeology (Roll et al. 2005) (included in this volume as Appendix C) .

C XRF Analysis of Obsidian from Camp Baker Quarry

Arguably, virtually all materials found at the Camp Baker Quarry derive from local sources-chert from the quarry pits, quartzite hammerstones and mauls from the bed of the Smith River, bone and antler from resident animals. Unquestionably, exotic materials consist of two pieces of obsidian. A small, translucent obsidian internal percussion flake (L – 13.84 mm, W – 26.00 mm, T – 4.06 mm, wt – 0.8 g) with a heavily ground platform appeared in the screen while excavating Pit 21, Unit 113, Level VI. Because of the surface slope on Pit 113, that provenience places the flake in the bottom of Stratum 1 or the top of Stratum 2. Toward the end of the project, while investigating the drainage about 400 m down slope from the Camp Baker Quarry, a member of the crew found a larger flake of obsidian (L – 34.43mm, W – 32.08 mm, T – 12.14 mm, Wt. – 8.1 g). That specimen consisted of a plain platform, cortical percussion flake. The context of the specimen, exposed on the surface in the bottom of the drainage, suggested it had either been recently exposed and transported from somewhat higher in the drainage or recently displaced from one of the numerous nearby rodent burrows. Chert flaking debris, consistent with that from the quarry, littered the surface in the vicinity of this lone piece of obsidian. The location of this find properly represents the western periphery of the Camp Baker Fishing Access Site (24ME75) (Aaberg 1983).

We submitted both pieces to Dr. Richard Hughes of the Geochemical Research Laboratory for trace element analysis by energy dispersive x-ray fluorescence (EDXRF or more commonly XRF). Hughes determined that both specimens possess trace element composition consistent with the Obsidian Cliff geochemical type, Wyoming (Appendix D). A mere 224 km (140 mi) of relatively easy terrain separate the Camp Baker Quarry from Obsidian Cliff, with most of the distance defined by permanent streams. Today, and probably for millennia in the past, once free of the rugged heavily forested terrain upstream from the mouth of Yankee Jim Canyon on the Yellowstone River immediately north of the Yellowstone National Park Boundary, open sage brush flats along river terraces characterize the remainder of the distance to Camp Baker.

The most important aspect of the identification of Obsidian Cliff obsidian at the Camp Baker Quarry revolves around the continued verification that people and goods circulated widely. As a highly desired toolstone, the Obsidian Cliff volcanic glass has a long history of use and wide distribution. Davis et al. (1995:39-58) summarize the then-known chronology and distribution of Obsidian Cliff obsidian. Documented Paleoindian use of Obsidian Cliff obsidian extends human utilization of the source back to greater than 10,000 BP. Geographically, the material had achieved distribution as far east as Ohio by Middle Woodland times, with more restricted, but still substantial, dispersal in other directions, particularly to the north and west. Very little evidence supports a similar early use and wide distribution for the Camp Baker Quarry toolstone, but the wide dissemination of the Obsidian Cliff obsidian documents the potential range of other desired materials.

VIII PREHISTORIC QUARRYING AT CAMP BAKER

The limited excavations at the Camp Baker Quarry yielded substantial quantities of quarry debris and debitage. From these data there should emerge some notion of the kinds of lithic modification activities that prevailed at the site. It appears the geological strata containing the desired chert resource developed in the Cambrian Age Park Shale that dominates the immediate area, perhaps in one or more of the thin, alternating bands of limestone common to the Park Shale. A prominent igneous intrusion likely provided the source of silica-rich hydrothermal waters that led to the silicification that produced the chert. For several kilometers north or south of Camp Baker, the geologic structures consist of "...high-angle thrust faults that strike toward the northwest and dip toward the southwest" (Hruska 1967:72). These upthrusts have exposed the sediments to erosional processes. It appears the Camp Baker Quarry originally consisted of chert seams or chimneys encased in shale/limestone bedrock. Erosion of the softer bedrock exposed chert-bearing sediment. Prehistoric people identified the chert as a valuable resource for stone tool manufacture and began utilizing surface exposures. After exhausting chert on, or near, the surface, they probably followed chert-bearing seams downward until the effort invested in securing the desired stone exceeded the work required to open a new pit, or improve on a pre-existing pit.

The results of the debitage analysis indicate that procurement of raw material for manufacture of stone tools was the principal activity of the prehistoric people who used the site. The berms or "debitage aprons" (Schmitt, et al. 1992:27) contain the remains of quarry debris (material removed in the process of acquiring useful stone, but not necessarily useful in itself), the deposited remains of independent lithic reduction episodes, and materials incorporated in the apron through natural processes (gravity, hydraulic movement, aeolian processes, bedrock decomposition, etc), mostly sand and silt-sized sediment. In our excavations, we found virtually nothing suggesting the implements used to extract the desired stone. Other than very small flecks of bone, a single fragment, probably of antler, provided the only item potentially consistent with the bone and antler implements found at other quarry sites such as the Schmitt Chert Mine near the Missouri River north of Three Forks, Montana (Davis 1983; Davis, et al. 1978).

Having acquired the basic raw material, the next major concern probably involved testing to evaluate the piece for quality by removing several flakes. The debitage aprons contained many large chunks with one or more flake scars that reveal the reason for their abandonment.

Typically the interiors of these pieces display fractures, grainy structure, incomplete silicification, or other conditions that led to their discard. It addition to these pieces, we also found a surprising number of large seemingly useful pieces with no modification beyond the removal of one or more flakes. Perhaps the prehistoric knappers selected their toolstone based on criteria other than those some modern practitioners might use, or, faced with more stone than needed at any one time, they may have simply culled out the most desirable, leaving other useful, but less desirable pieces behind.

The next step in the reduction process seems to have entailed the removal of cortex (if the piece contained cortex) and other undesired portions to produce a blank of a shape and size sufficient to permit manufacture of desired cores and flake blanks. This manufacturing stage created the majority of the post-quarrying debitage present in the aprons. Our analysis identified virtually no evidence for any form of reduction other than direct hard-hammer percussion. The high frequency of unprepared platforms, particularly plain or flat platforms (Figure 25 and Figure 26) lends credence to the notion of an emphasis on hard-hammer reduction. Several instances of possible bipolar reduction represent such a small portion of the assemblage as to eliminate this form of core reduction as common at Camp Baker. The number of classic bifacial reduction flakes is equally small, and analysts identified no incontrovertible examples of billet or soft hammer reduction (Crabtree 1972; Whitaker 1994). From the foregoing discussion, it is not unexpected that in the analyzed debitage sample, we found no evidence of pressure flaking (pressure flakes).

From the analysis of the Camp Baker debitage, it appears that on-the-spot reduction generally ceased upon creation of an appropriately sized core or flake blank. Further reduction and tool manufacture, from that point onward, must have taken place in other locations in the vicinity of the quarry, or cores and flake blanks were transported to other locations for caching or additional processing.

A small proportion of the debris, mostly either dark brown or dark gray mottled chert, frequently possesses the vitreous, waxy sheen observed of some heat-treated silica materials (Crabtree and Butler 1964; Purdy 1974; Luedtke 1992:94-95). This characteristic appears prominently on fractured surfaces exposed after thermal alteration. A large void exists in our ability to reliably identify thermally altered cherts and, more importantly, our ability to separate deliberate, cultural alteration of chert from accidental or natural processes that yield visually identical results. Beyond the appearance of the chert itself, archaeologists have rarely secured independent confirmation of the practice in the form of identifiable heat-treating facilities (hearths, ovens, etc.) or related features (Griffiths, et al. 1987). Because of the difficulty of producing uniform results and the high failure rates resulting from thermal shock while attempting to alter large pieces, modern knappers rarely apply heat-treatment to large blocks or cores, but reserve its application for smaller bifacial cores or preforms. Once heat-treated, chert from many sources becomes more compliant to flaking, but heat treating works best when applied to relatively thin pieces (Crabtree 1966:1; Mandeville 1973:191). At Tosawihi, a large quarry site in the northern Great Basin, Elston (1992:792) observed that stage 3 bifaces (primarily thinned, but with little or no secondary thinning) represent the most commonly selected stage for heat-treating. The absence of evidence for heat-treating at the Camp Baker Quarry itself is not too surprising given the nature of the debitage. Virtually nothing found at the quarry indicates either bifacial core production or tool manufacture, particularly the manufacture

of bifacial implements, occurred commonly at the quarry. We conclude the vitreous appearance of some debitage from Camp Baker results primarily from a mechanism(s) other than deliberate thermal alteration, possibly related to the context of formation.

Our understanding of the activities at the Camp Baker Quarries remains preliminary; however, a number of trends can be identified. Materials recovered represent several types of activities—quarrying and initial roughing out of cores. The density and character of the lithic remains support this interpretation. In particular, the debitage does not represent extensive bifacial shaping and thinning. Most of the reduction appears to involve flake removal from amorphous, mostly sharp-sided or angular, blocks intended for subsequent modification at other locations. The relative absence of discarded formal tools, either complete or broken, suggests toolkit maintenance or replacement took place elsewhere. As an extraction locality with few attractions beyond the high-quality raw material for stone tool manufacture, these results hold few surprises. Substantial campsites with diverse artifact assemblages appear on alluvial fans and terraces along the nearby Smith River and lithic scatters on open slopes to the south attest to a wide range of cultural activities. Given this array of local resources, we suggest that mobile populations camping elsewhere in the region made forays to the quarries for raw material. Arguments as to the nature of these visitations, whether logistical or residential, must await additional research. In particular, the chronology of quarry use, and assessment of the distributional range of toolstones from the Smith River area should contribute substantially to understanding of prehistoric human mobility patterns in the Northwestern Great Plains.

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Appendix A

LA-ICP-MS Analysis of Chert from Camp Baker Quarry

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Laser Ablation ICP-MS Analysis of Chert from the Camp Baker Quarry Site (24ME467), Montana

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Introduction

Roll (2002) is investigating lithic resource use patterns in the Northwestern Great Plains. Towards this end he has submitted sixteen chert source samples from the Camp Baker Quarry site (24ME467) located in the Big Belt Mountains of Central Montana. The samples were characterized at the University of Missouri Research Reactor (MURR) using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS).

Description of Laser Ablation ICP-MS

Since the first archaeometric uses of inductively coupled plasma (ICP) in the early 1980s (e.g., Hart and Adams 1983; Hart et al. 1987), most applications have required digestion of solid samples with heat and/or strong acids, which is both time consuming and unpleasant. An alternative sample-introduction technique, laser-ablation, was first applied in the mid 1980s by Gray (1985) and became commercially available in the early to mid-1990s, (e.g., Campbell and Humayun 1999; Pollard and Heron 1996). The coupling of laser-ablation (LA) with state-of-the art inductively coupled plasma-mass spectrometers (ICP-MS) has resulted in the development of extremely sensitive microprobes capable of determining most elements of the periodic table. The potential of LA-ICP-MS has been recognized in various scientific fields, including the earth sciences (e.g., Jackson 2001; Jackson et al. 2001; Jeffries et al. 1995; Norman 2001; Sylvester 2001), zoology (e.g., Campana 1999; Sinclair et al. 1998; Thorrold et al. 1997), botany (Hoffman et al. 1994; Watling 1998; Watmough et al. 1998), ecology (e.g., Garbeschonberg et al. 1997; Raith et al. 1996), and archaeology (e.g., Devos et al. 2000; Kennett et al. 2001; Neff 2003; Pollard and Heron 1996; Tykot 2002). As a result, LA-ICP-MS has become one of the most exciting new fields of research in materials science. Future developments in instrumentation, applications, and data calibration methods may only serve to generate additional interest in this technique.

At MURR, LA-ICP-MS has been used to characterize a variety of archaeological materials (Speakman et al. 2002). Some of these projects include characterization of paints on pottery from the Mesa Verde region (Speakman and Neff 2002), Mexico (Rodriguez 2002), and Turkey (Diebold 2002); analysis of glazes on Mesoamerican Plumbate pottery (Neff 2003) and historic Euro American pottery; characterization of glass beads (Glascock and Speakman 2002), Midwestern cherts (Speakman et al. 2001), obsidian (Sall et al. 2001), turquoise (Zedeño et al 2002); and determination of inclusions in pottery (Larson et al. 2002). These studies have consistently demonstrated the potential of LA-ICP-MS for chemical characterization studies.

Unlike INAA or ICP-MS of solutions, which produces a bulk chemical data representative of the analyzed sample, LA-ICP-MS is point specific, that is, only the area ablated is subject to analysis. Attempting to obtain bulk compositional data on heterogeneous samples such as pottery is challenging due to spatial variation in the sample (e.g., clay and temper particles). On the other hand, homogeneous samples such as obsidian and to a certain extent chert are ideally suited for this type of analysis because spatial variation is minimal in these materials. ICP-MS can provide compositional data for 130+ isotopes, including rare earth elements, whereas INAA typically provides compositional data for about 30-35 different

elements. Some elements, such as Pb, Bi, Sn, Mg, and P, which cannot be measured by INAA but can be measured by LA-ICP-MS, may prove important for separating materials into different compositional groups. For certain elements LA-ICP-MS has superior detection limits to INAA (e.g., Ni, V, Sr, Sb, Ba, Zr).

In LA-ICP-MS a laser is used to ablate a small area on the surface of a sample. At MURR, the area ablated is usually along a line or small raster and the laser usually ablates less than 10 microns into the sample. The ablated material is transported from the laser cell and introduced into the ICP-MS torch where an argon gas plasma capable of sustaining electron temperatures between 8000 and 10000 K is used to ionize the injected sample. The resulting ions are then accelerated by a high voltage and passed through a series of focusing lenses, an electrostatic analyzer, and finally a magnet. By varying the strength of the magnet, ions are separated according to mass/charge ratio and passed through a slit into the detector which records only a very small atomic mass range at a given time. By varying the instrument settings the entire mass range can be scanned within a short period of time.

The instrument used in the study reported here is a Thermo Elemental Axiom magnetic-sector inductively coupled plasma mass spectrometer that can resolve atomic masses as close as 0.001 atomic mass units apart, thus eliminating many polyatomic and isobaric interferences that pose problems for quadrupole ICP-MS instruments. The ICP-MS is coupled to a Merchantek Nd:YAG 213-nanometer wavelength laser ablation unit, which permits the introduction of solid samples into the ICP-MS. The laser can be targeted on spots as small as ten microns in diameter. With this small spot size and the very high sensitivity of magnetic sector ICP-MS to a wide range of major, minor, and trace elements, LA-ICP-MS is a very powerful microprobe. Moreover it is virtually non-destructive to most samples, considering that the ablated areas are often indistinguishable with the naked eye.

Laser Ablation ICP-MS Sample Preparation

Laser ablation ICP-MS requires little sample preparation other than resizing the sample to fit inside the sample chamber. For this study, samples were washed in deionized water and permitted to dry. Each sample was then crushed into coarse fragments. Relatively flat interior fragments with little or no cortex were selected for analysis.

Laser Ablation ICP-MS Analytic Parameters

Prior to data acquisition, the instrument is turned-on and permitted to warm-up for a minimum of one hour. Allowing the instrument to warm-up permits the internal components to reach their optimum operating temperature, greatly reducing instrument noise and drift. After an hour or so, a glass standard (NIST SRM 612, a glass wafer spiked with 60+ elements) was placed in the laser chamber and continuously ablated to produce a signal that permits the instrument settings to be adjusted so that sensitivity is maximized while noise is minimized. After tuning the instrument, data for a blank and two standards were collected, NIST SRM-612 and NIST SRM-610, and an in-house standard, Ohio Red Clay fired to 1200 °C. Following collection of the standard data, the samples were placed in the laser cell and analyzed. Data for

additional standards were collected midway through the analysis and at the conclusion of the analysis.

With most research that concern laser ablation ICP-MS, the laser power settings are reported as a percentage of the maximum power setting of the laser. For example, *Researcher A* may report the laser was operated at 90% power during the experiment while another researcher may report 60% power as the experimental parameter. A fundamental problem with this approach is that each laser has a different maximum power output. Additionally, the age of the laser, the amount of use/abuse the laser has been subject to, and the alignment of the internal laser components affect the power output and thus the interaction of the laser with the surface of the sample. To further complicate the matter, each individual ICP or ICP-MS operates under different sets of operating conditions which can and do change daily. As a result, *Researcher A* may operate a laser at high power, but may have a laser ablation system or ICP-MS instrument that is not efficiently optimized. *Researcher B* may operate the laser at a lower power setting but have an ICP instrument that is more efficiently tuned. Consequently, it is possible that *Researcher B* may be able to obtain better counting statistics than *Researcher A*.

Some researchers also believe that applying the maximum laser power settings to an inorganic sample matrix is an appropriate experimental condition, especially for sample matrices that are texturally hard. However, if the laser introduces too much material into the torch at any given time, signal stability will decrease since the plasma is not able to effectively ionize all of the ablated material. Additionally, the introduction of excess material will result in the sample and skimmer cones becoming clogged throughout the day which will lower the precision of the counting statistics and introduce unnecessary error into the experiment.

In order to compensate for the problem of determining the best laser power settings, we tune the ICP-MS to maximize signal intensity then adjust the laser power settings to bring the signal up or down to a predetermined count rate depending on the sample matrix—usually 600,000–1,200,000 counts per second of indium on NIST SRM 612 using a 200 micron diameter beam, firing 20 shots per second, scanning along a line at a speed of 70 microns per second.

Ablation parameters were identical for all unknowns and standards analyzed. The laser was rastered over a line placed over the enamel and dentine of each sample. The laser was operated using a 200 micron wide beam, firing 20 shots per second, scanning along a line at a speed of 70 microns per second. The laser beam was permitted to pass over the ablation area twice prior to data acquisition in order to remove contamination from the surface of the samples, to permit time for sample uptake, and to permit time for the argon gas plasma to stabilize after the introduction of the ablated material. Our experiments at MURR have demonstrated that pre-ablation permits the laser to couple better with the sample matrix. Analytes of interest were scanned three times and averaged.

Normalization and Standardization of Laser Ablation ICP-MS Data

A basic problem in LA-ICP-MS is that it is difficult to monitor the amount of material removed by the laser and transported to the ICP. Conditions such as hardness of the material, position of the sample in the laser chamber, whether or not the surface of the artifact is flat, and

other conditions clearly affect how much material reaches the ICP torch and thus the intensity of the signal monitored for the various atomic masses of interest. In addition, instrumental drift in the ICP-MS over several hours or days affects count rates.

With liquid samples internal samples are typically used to counteract instrument drift, but this approach is not available when material for the analysis is ablated from an intact solid sample. If one or more elements can be determined or assumed independently, then these can serve as quasi-internal standards. In the case of rhyolitic obsidian which has relatively consistent silicon concentrations (ca. ~36%), we have determined that silicon count rates can be normalized to a common value. This value divided by the actual number of counts produces a normalization factor from which all the other elements in that sample can be multiplied. However with most sample matrices, we have determined that the best data calibration method is to use an approach suggested by Gratuze (Gratuze et al. 2001; but also see Neff 2003 and Speakman 2002). Experiments with a wide range of materials types (primarily obsidian, glass, and ceramics) demonstrate the superiority of this approach.

The Gratuze method (Gratuze et al. 2001; Neff 2003, Speakman 2002) involves correcting blank-subtracted raw counts for isotopic abundance. The signal for every element is then standardized by calculating a ratio to the counts for a single element, the "internal standard":

$$std\ \ signal_y = \frac{counts_y}{counts_{\ internal\ standard}}$$

The standardized signals are also related to the response coefficients, K_y:

$$std\ \ signal_y = K_y\left(\frac{conc_y}{conc_{\ internal\ standard}}\right)$$

The *Ky's* can then be obtained from the multielement standards by:

$$K_y = std\ signal_y\ in\ ref.material\left(\frac{conc_{\ internal\ standard}\ in\ ref\ material}{conc_y\ in\ ref\ material}\right)$$

Total oxide composition of each specimen can then be calculated by:

$$oxide\ conc_y = \left(\frac{O_y(std\ signal_y)/K_y}{\sum_{i=1}^{m} O_i(std\ signal_i)/K_i}\right)100$$

The basic assumption of the Gratuze approach is that the 40+ elements being measured represent essentially all of the material, other than oxygen, that is ablated from the sample. Oxygen is then taken into consideration by converting the elemental signals to signals of their oxides. Phosphorous and calcium were converted to the mineral apatite rather than their elemental oxides. Some error may be introduced at this point for elements that occur in more than one oxidation state, particularly iron, which may be present as FeO as well as Fe_2O_3. Additionally, any water in the material is unaccounted for in the summation to 100%, as are some elements, such as chlorine and fluorine which may be present but are not measured. These missing measurements may contribute to a slight overestimation of the various measured oxides.

Quantitative Analysis of the Chemical Data

The analyses at MURR described previously produced elemental concentration values 45 elements by LA-ICP-MS in most of the analyzed samples. Quantitative analysis was subsequently carried out on base-10 logarithms of concentrations for these data. Use of log concentrations instead of raw data compensates for differences in magnitude between major elements, such as iron, on one hand and trace elements, such as the rare earth or lanthanide elements (REEs), on the other hand. Transformation to base-10 logarithms also yields a more nearly normal distribution for many trace elements.

The goal of quantitative analysis of the chemical data is to recognize compositionally homogeneous groups within the analytical dataset. Based on the “provenance postulate” (Weigand, Harbottle, and Sayre 1977), such groups are assumed to represent geographically restricted sources or source zones. The location of sources or source zones may be inferred by comparing the unknown groups to knowns (source raw materials) or by indirect means. Such indirect means include the “criterion of abundance” (Bishop, Rands, and Holley 1982) or arguments based on geological and sedimentological characteristics (e.g., Steponaitis, Blackman, and Neff 1996).

Initial hypotheses about source-related subgroups in the compositional data can be derived from non-compositional information (e.g., archaeological context, decorative attributes, etc.) or from application of pattern-recognition techniques to the chemical data. Principal components analysis (PCA) is one technique that can be used to recognize pattern (i.e., subgroups) in compositional data. PCA provides new reference axes that are arranged in decreasing order of variance subsumed. The data can be displayed on combinations of these new axes, just as they can be displayed relative to the original elemental concentration axes. PCA can be used in a pure pattern-recognition mode, i.e., to search for subgroups in an undifferentiated data set, or in a more evaluative mode, i.e., to assess the coherence of hypothetical groups suggested by other criteria (archaeological context, decoration, etc.). Generally, compositional differences between specimens can be expected to be larger for specimens in different groups than for specimens in the same group, and this implies that groups should be detectable as distinct areas of high point density on plots of the first few components.

One often exploited strength of PCA, discussed by Baxter (1992) and Neff (1994), is that it can be applied as a simultaneous R- and Q-mode technique, with both variables (elements) and objects (individual analyzed samples) displayed on the same set of principal component

reference axes. The two-dimensional plot of element coordinates on the first two principal components is the best possible two-dimensional representation of the correlation or variance-covariance structure in the data: Small angles between vectors from the origin to variable coordinates indicate strong positive correlation; angles close to 90° indicate no correlation; and angles close to 180° indicate negative correlation. Likewise, the plot of object coordinates is the best two-dimensional representation of Euclidean relations among the objects in log-concentration space (if the PCA was based on the variance-covariance matrix) or standardized log-concentration space (if the PCA was based on the correlation matrix). Displaying objects and variables on the same plots makes it possible to observe the contributions of specific elements to group separation and to the distinctive shapes of the various groups. Such a plot is called a "biplot" in reference to the simultaneous plotting of objects and variables. The variable interrelationships inferred from a biplot can be verified directly by inspection of bivariate elemental concentration plots (note that a bivariate plot of elemental concentrations is not a "biplot").

Whether a group is discriminated easily from other groups can be evaluated visually in two dimensions or statistically in multiple dimensions. A metric known as Mahalanobis distance (or generalized distance) makes it possible to describe the separation between groups or between individual points and groups on multiple dimensions. The Mahalanobis distance of a specimen from a group centroid (Bieber et al. 1976; Bishop and Neff 1989; Neff 2002; Harbottle 1976; Sayre 1975) is:

$$D^2_{y,X} = [y - \overline{X}\,]^t\, I_X\, [y - \overline{X}\,]$$

where y is 1 x m array of logged elemental concentrations for the individual point of interest, X is the n x m data matrix of logged concentrations for the group to which the point is being compared with $\overline{X}$ being its 1 x m centroid, and I_x is the inverse of the m x m variance-covariance matrix of group X. Because Mahalanobis distance takes into account variances and covariances in the multivariate group it is analogous to expressing distance from a univariate mean in standard deviation units. Like standard deviation units, Mahalanobis distances can be converted into probabilities of group membership for each individual specimen (e.g., Bieber et al. 1976; Bishop and Neff 1989; Harbottle 1976). For relatively small sample sizes, it is appropriate to base probabilities on Hotelling's T^2, which is a multivariate extension of the univariate Student's t.

With small groups, Mahalanobis distance-based probabilities of group membership may fluctuate dramatically depending on whether or not each specimen is assumed to be a member of the group to which it is being compared. Harbottle (1976) calls this phenomenon "stretchability" in reference to the tendency of an included specimen to stretch the group in the direction of its own location in the elemental concentration space. This problem can be circumvented by cross-validation (or "jackknifing"), that is, by removing each specimen from its presumed group before calculating its own probability of membership (Baxter 1994; Leese and Main 1994). This is a conservative approach to group evaluation that may sometimes exclude true group members. All probabilities discussed below are cross-validated.

Small sample and group size places a further constraint on use of Mahalanobis distance: with more variates than objects, the group variance-covariance matrix is singular thus rendering calculation of I_x (and D^2 itself) impossible. Dimensionality of the groups therefore must be reduced somehow. One approach to dimensionality reduction would be to eliminate elements considered irrelevant or redundant. The problem with this approach is that the investigator's preconceptions about which elements should best discriminate sources may not be valid; it also squanders one of the major strengths of ICP-MS, namely the capability to determine a large number of elements. An alternative approach to dimensionality reduction, used here, is to calculate Mahalanobis distances not with log concentrations but with scores on principal components extracted from the variance-covariance or correlation matrix of the complete data set. This approach entails only the assumption, entirely reasonable in light of the above discussion of PCA, that most group-separating differences should be visible on the largest several components. Unless a data set is highly complex, with numerous distinct groups, using enough components to subsume 90% of total variance in the data may be expected to yield Mahalanobis distances that approximate Mahalanobis distances in the full elemental concentration space.

Results and Conclusion

The diskette enclosed with this report contains descriptive and compositional data for the sixteen chert samples analyzed in this study. Values of 0.0 (contained in spreadsheet) indicate the concentration for that element is below the instrument detection limits for that sample and is not meant to imply that the element is completely absent from the sample. Table 1 presents descriptive data and compositional group assignments for the analyzed samples.

Due to the relatively small sample size (n=16) and heterogeneous nature of chert, analytes of interest were scanned three times each and averaged (as discussed above), but, each sample was also analyzed at three discrete locations on each sample. In other words, data were generated for each element a total of nine times for each sample. Rather than average the data obtained from the three locations, each analysis at each location is treated as a separate sample. This effectively permits 1) the sample size to be increased from 16 to 48, and, 2) permits variation within samples to be observed (see Figures 2, 4, 6, and 8). Additionally, samples CBQ3, 14, and 16 contained two distinct colors/structures and sample CBQ8 contained three distinct colors/structures within the sample. In these cases, each distinct color/structure was also analyzed at three discrete locations. This resulted in the number of LA-ICP-MS analyses increasing from 48 to 63.

The *increased* sample size permitted probabilities of group membership to be generated using Mahalanobis Distance (Table 2). Table 2 presents the probabilities of membership for Groups 2 and 3 based the first six principal components which subsume more than 90% of the variation (Table 3). This might not be the most appropriate use of Mahalanobis Distance since each sample is represented in each compositional group at least three times and can result in artificially inflating probabilities of group membership. However, this technique does provide a means for compensating for the small sample size and while the same sample is represented several time, they are nonetheless a separate analyses. In next phase of this project, the sample size will presumably be increased such that this approach will not be necessary.

Figures 1–8 present the basic subgroup structure identified through analysis of the LA-ICP-MS data. Figure 1 (and 2) is a biplot derived from PCA variance-covariance matrix biplot derived from the 63 sample data set. It shows that the major axis of variation in the data (Principal Component 1) expresses enrichment of most elements except for several of the first row transition metals, lead, arsenic, and antimony.

Figure 3–8 are bivariate plots derived from base-10 logged concentrations of various elements. Of interest is the distinctness of two main compositional groups (Groups 2 and 3) in the projections of the data.

Three groups were identified during this analysis. Group 1 consists of three replicates of the same sample and contains higher concentrations of most elements except silica. This would seem to indicate that the sample may not be a chert (i.e., possibly a mudstone) or may represent a chert source not extensively sampled for this pilot study. Group 2 is distinguished from Group 3 on the basis of higher elemental concentrations for most elements. It is possible, for Group 3 in particular, that multiple chemical subgroups may be represented in the analyzed sample. Additional sampling of chert from Camp Baker Quarry may shed light on this question.

Viewed from the perspective of a pilot project, this study can be considered a success. Due to inherent chemical variability within sources, chert is difficult to analyze by any analytical technique. The fact that such clear-cut chemical groups were identified within this small sample suggests that analysis of cherts from Montana may be a rewarding endeavor. Additional analyses should focus on geographically and geologically distinct source samples from Camp Baker Quarry. Ideally, this should provide information on chemical variability in cherts throughout the region. Should the next phase prove successful, the study should be expanded to include archaeological tools and debitage.

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Figure Captions

Figure 1: Variation-covariation matrix PCA biplot of principal components 1 and 2 for the 45 elements determined for the Camp Baker Quarry study. Ellipses represent 90% confidence level for membership in the groups.

Figure 2: Same PCA space as Figure 1, individual specimens are labeled.

Figure 3: Bivariate plot of magnesium and calcium base-10 logged concentrations for the Camp Baker Quarry data. Ellipses represent 90% confidence level for group membership.

Figure 4: Same as Figure 3, individual specimens are labeled.

Figure 5: Bivariate plot of chromium and vanadium base-10 logged concentrations for the Camp Baker Quarry data. Ellipses represent 90% confidence level for group membership.

Figure 6: Same as Figure 5, individual specimens are labeled.

Figure 7: Bivariate plot of cesium and zinc base-10 logged concentrations for the Camp Baker Quarry data. Ellipses represent 90% confidence level for group membership.

Figure 8: Same as Figure 7, individual specimens are labeled.

Table 1. Group assignments and descriptive information for Camp Baker Quarry chert samples

ANID	CHEM02	COLOR	SITE_NAME	SITE_NO	CONTEXT	PROVENANCE
CBQ1a	Group 3	brown	Camp Baker Quarry	24ME467	pit 21	BC
CBQ1b	Group 3	brown	Camp Baker Quarry	24ME467	pit 21	BC
CBQ1c	Group 3	brown	Camp Baker Quarry	24ME467	pit 21	BC
CBQ2a	Group 3	Dark brown	Camp Baker Quarry	24ME467	pit 21	BC
CBQ2b	Group 3	Dark brown	Camp Baker Quarry	24ME467	pit 21	BC
CBQ2c	Group 3	Dark brown	Camp Baker Quarry	24ME467	pit 21	BC
CBQ3Aa	Group 3	gray	Camp Baker Quarry	24ME467	pit 21	BC
CBQ3Ab	Group 3	gray	Camp Baker Quarry	24ME467	pit 21	BC
CBQ3Ac	Group 3	gray	Camp Baker Quarry	24ME467	pit 21	BC
CBQ3Ba	Group 3	Dark gray	Camp Baker Quarry	24ME467	pit 21	BC
CBQ3Bb	Group 3	Dark gray	Camp Baker Quarry	24ME467	pit 21	BC
CBQ3Bc	Group 3	Dark gray	Camp Baker Quarry	24ME467	pit 21	BC
CBQ4a	Group 3	Dark gray	Camp Baker Quarry	24ME467	pit 21	BC
CBQ4b	Group 3	Dark gray	Camp Baker Quarry	24ME467	pit 21	BC
CBQ4c	Group 3	Dark gray	Camp Baker Quarry	24ME467	pit 21	BC
CBQ5a	Group 2	Tan	Camp Baker Quarry	24ME467	pit 21	BC
CBQ5b	Group 2	Tan	Camp Baker Quarry	24ME467	pit 21	BC
CBQ5c	Group 2	Tan	Camp Baker Quarry	24ME467	pit 21	BC
CBQ6a	Group 2	Gray	Camp Baker Quarry	24ME467	pit 21	BC
CBQ6b	Group 2	gray	Camp Baker Quarry	24ME467	pit 21	BC
CBQ6c	Group 2	Gray	Camp Baker Quarry	24ME467	pit 21	BC
CBQ7a	Group 3	Gray	Camp Baker Quarry	24ME467	pit 21	VI
CBQ7b	Group 3	gray	Camp Baker Quarry	24ME467	pit 21	VI
CBQ7c	Group 3	Gray	Camp Baker Quarry	24ME467	pit 21	VI
CBQ8Aa	Group 3	brown	Camp Baker Quarry	24ME467	pit 21	VI
CBQ8Ab	Group 3	brown	Camp Baker Quarry	24ME467	pit 21	VI
CBQ8Ac	Group 3	brown	Camp Baker Quarry	24ME467	pit 21	VI
CBQ8Ba	Group 2	Red	Camp Baker Quarry	24ME467	pit 21	VI
CBQ8Bb	Group 2	Red	Camp Baker Quarry	24ME467	pit 21	VI
CBQ8Bc	Group 2	Red	Camp Baker Quarry	24ME467	pit 21	VI
CBQ8Ca	Group 2	gray	Camp Baker Quarry	24ME467	pit 21	VI
CBQ8Cb	Group 2	gray	Camp Baker Quarry	24ME467	pit 21	VI

Table 1 (continued). Group assignments and descriptive information for Camp Baker Quarry chert samples

ANID	CHEM02	COLOR	SITE_NAME	SITE_NO	CONTEXT	PROVENANCE
CBQ8Cc	Group 2	Gray	Camp Baker Quarry	24ME467	pit 21	VI
CBQ9a	Group 1	Tan	Camp Baker Quarry	24ME467	pit 21	VI
CBQ9b	Group 1	Tan	Camp Baker Quarry	24ME467	pit 21	VI
CBQ9c	Group 1	Tan	Camp Baker Quarry	24ME467	pit 21	VI
CBQ10a	Group 3	brown	Camp Baker Quarry	24ME467	pit 21	VI
CBQ10b	Group 3	Brown	Camp Baker Quarry	24ME467	pit 21	VI
CBQ10c	Group 3	brown	Camp Baker Quarry	24ME467	pit 21	VI
CBQ11a	Group 3	Tan	Camp Baker Quarry	24ME467	pit 21	VII
CBQ11b	Group 3	Tan	Camp Baker Quarry	24ME467	pit 21	VII
CBQ11c	Group 3	Tan	Camp Baker Quarry	24ME467	pit 21	VII
CBQ12a	Group 3	brown	Camp Baker Quarry	24ME467	pit 21	VII
CBQ12b	Group 3	Brown	Camp Baker Quarry	24ME467	pit 21	VII
CBQ12c	Group 3	Brown	Camp Baker Quarry	24ME467	pit 21	VII
CBQ13a	Group 2	Brown	Camp Baker Quarry	24ME467	pit 21	VIII
CBQ13b	Group 2	Brown	Camp Baker Quarry	24ME467	pit 21	VIII
CBQ13c	Group 2	Brown	Camp Baker Quarry	24ME467	pit 21	VIII
CBQ14Aa	Group 3	black	Camp Baker Quarry	24ME467	pit 21	VIII
CBQ14Ab	Group 3	Black	Camp Baker Quarry	24ME467	pit 21	VIII
CBQ14Ac	Group 3	Black	Camp Baker Quarry	24ME467	pit 21	VIII
CBQ14Ba	Group 3	Gray	Camp Baker Quarry	24ME467	pit 21	VIII
CBQ14Bb	Group 3	Gray	Camp Baker Quarry	24ME467	pit 21	VIII
CBQ14Bc	Group 3	Gray	Camp Baker Quarry	24ME467	pit 21	VIII
CBQ15a	Group 3	Tan	Camp Baker Quarry	24ME467	pit 21	VII
CBQ15b	Group 3	Tan	Camp Baker Quarry	24ME467	pit 21	VII
CBQ15c	Group 3	Tan	Camp Baker Quarry	24ME467	pit 21	VII
CBQ16Aa	Group 2	brown	Camp Baker Quarry	24ME467	pit 21	III
CBQ16Ab	Group 2	brown	Camp Baker Quarry	24ME467	pit 21	III
CBQ16Ac	Group 2	brown	Camp Baker Quarry	24ME467	pit 21	III
CBQ16Ba	Group 3	gray	Camp Baker Quarry	24ME467	pit 21	III
CBQ16Bb	Group 3	gray	Camp Baker Quarry	24ME467	pit 21	III
CBQ16Bc	Group 3	gray	Camp Baker Quarry	24ME467	pit 21	III

Table 2. Mahalanobis Distance Calculation and Posterior Classification for Camp Baker Quarry Samples.

Variables used are: PC01 PC02 PC03 PC04 PC05 PC06

Probabilities are jackknifed for specimens included in each group.

The following specimens are in the file P2

ID. NO.	Probabilities: P2	P3	From:	Into:
CBQ5a	20.043	0.752	1	1
CBQ5b	0.758	0.258	1	1
CBQ5c	58.883	0.090	1	1
CBQ6a	66.674	0.031	1	1
CBQ6b	67.235	0.033	1	1
CBQ6c	8.660	0.017	1	1
CBQ8Ba	30.159	0.023	1	1
CBQ8Bb	61.489	0.000	1	1
CBQ8Bc	80.280	0.001	1	1
CBQ8Ca	26.067	0.012	1	1
CBQ8Cb	97.321	0.004	1	1
CBQ8Cc	48.853	0.002	1	1
CBQ13a	20.287	0.002	1	1
CBQ13b	45.473	0.001	1	1
CBQ13c	49.486	0.001	1	1
CBQ16Aa	80.144	0.008	1	1
CBQ16Ab	66.865	0.121	1	1
CBQ16Ac	84.029	0.000	1	1

The following specimens are in the file P3

ID. NO.	Probabilities: P2	P3	From:	Into:
CBQ1a	0.025	14.791	2	2
CBQ1b	0.002	0.035	2	2
CBQ1c	0.019	42.022	2	2
CBQ2a	0.145	90.953	2	2
CBQ2b	0.010	8.614	2	2
CBQ2c	0.027	94.439	2	2

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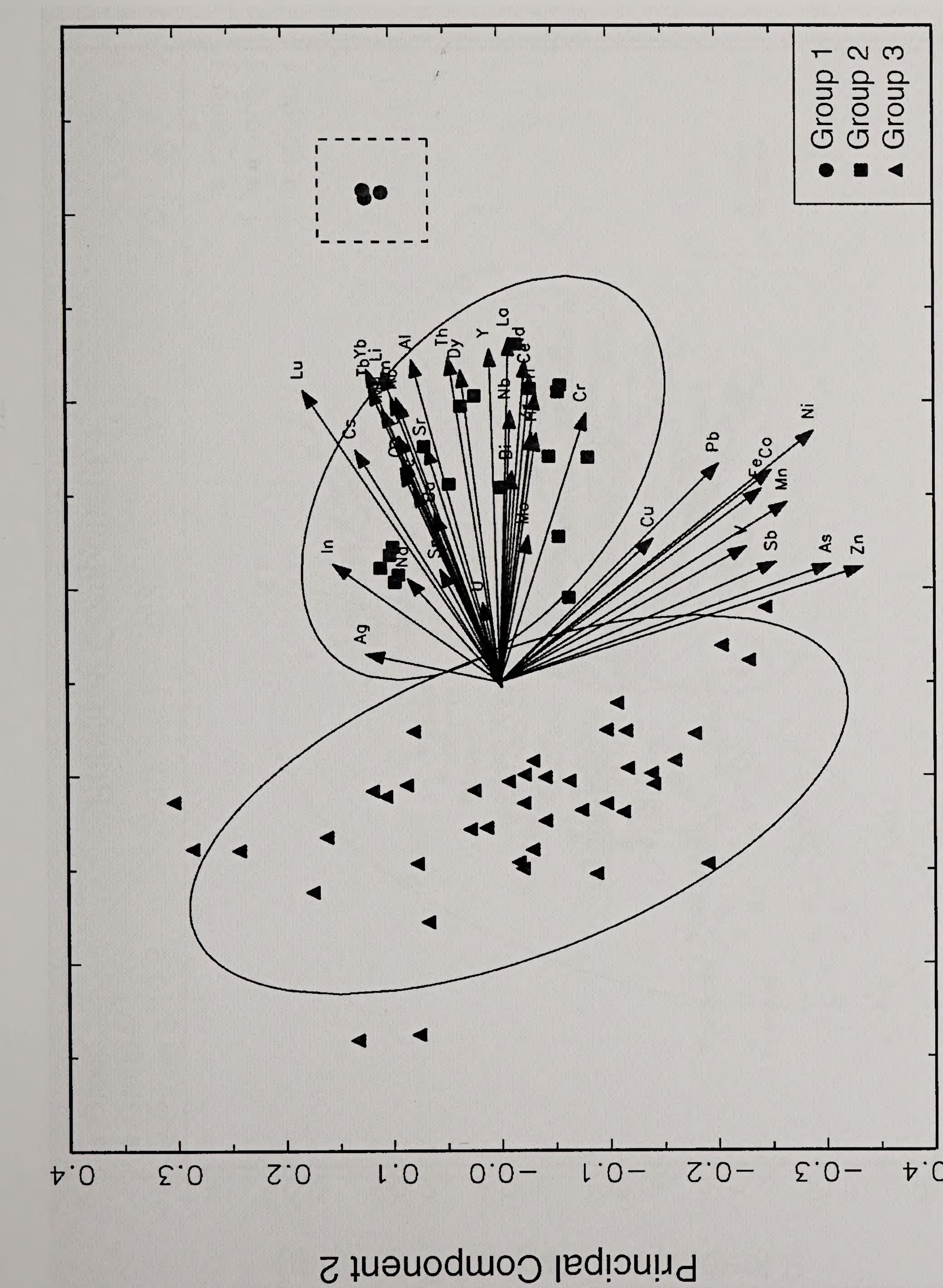
Table 2 (continued). Mahalanobis Distance Calculation and Posterior Classification for Camp Baker Quarry Samples.

CBQ3Aa	0.143	86.970	2	2
CBQ3Ab	0.028	88.291	2	2
CBQ3Ac	0.090	66.972	2	2
CBQ3Ba	0.014	74.397	2	2
CBQ3Bb	0.511	98.086	2	2
CBQ3Bc	0.090	99.346	2	2
CBQ4a	0.425	38.544	2	2
CBQ4b	0.138	27.425	2	2
CBQ4c	0.079	30.134	2	2
CBQ7a	1.404	16.831	2	2
CBQ7b	1.313	44.679	2	2
CBQ7c	0.705	55.213	2	2
CBQ8Aa	0.649	88.150	2	2
CBQ8Ab	0.419	64.345	2	2
CBQ8Ac	0.254	55.878	2	2
CBQ10a	0.061	40.313	2	2
CBQ10b	0.047	74.284	2	2
CBQ10c	0.003	11.636	2	2
CBQ11a	0.706	89.258	2	2
CBQ11b	0.659	37.946	2	2
CBQ11c	0.558	47.770	2	2
CBQ12a	0.002	16.610	2	2
CBQ12b	0.000	20.921	2	2
CBQ12c	0.001	28.005	2	2
CBQ14Aa	0.268	94.808	2	2
CBQ14Ab	0.044	85.040	2	2
CBQ14Ac	0.349	88.422	2	2
CBQ14Ba	0.145	90.223	2	2
CBQ14Bb	0.137	30.221	2	2
CBQ14Bc	0.047	61.752	2	2
CBQ15a	0.110	21.831	2	2
CBQ15b	0.105	77.422	2	2
CBQ15c	0.368	43.660	2	2
CBQ16Ba	0.250	54.670	2	2
CBQ16Bb	0.006	4.862	2	2
CBQ16Bc	0.006	0.262	2	2

A21

Eigenvalue	%Variance	Cum. %Var.
11.50	75.99	75.99
0.9005	5.952	81.95
0.5017	3.316	85.26
0.3088	2.041	87.30
0.2717	1.796	89.10
0.2291	1.514	90.61
0.2026	1.339	91.95
0.1901	1.256	93.21
0.1356	0.8961	94.10
0.1249	0.8252	94.93
0.08288	0.5478	95.48
0.07939	0.5247	96.00
0.07206	0.4763	96.48
0.06415	0.4240	96.90
0.05711	0.3775	97.28
0.05606	0.3705	97.65
0.04572	0.3022	97.95
0.04304	0.2845	98.24
0.03751	0.2479	98.48
0.03160	0.2088	98.69
0.02842	0.1879	98.88
0.02240	0.1481	99.03
0.02081	0.1376	99.17
0.01908	0.1261	99.29
0.01575	0.1041	99.40
0.01384	0.09145	99.49
0.01328	0.08778	99.58
0.009746	0.06442	99.64
0.008789	0.05809	99.70
0.007350	0.04858	99.75
0.006891	0.04555	99.79
0.006228	0.04116	99.83
0.004449	0.02941	99.86
0.003971	0.02625	99.89
0.003515	0.02323	99.91
0.003195	0.02112	99.93
0.002682	0.01773	99.95
0.002346	0.01551	99.97
0.001611	0.01065	99.98
0.001137	0.007516	99.99
0.001039	0.006867	99.99
0.0005326	0.003520	100.0
0.0004714	0.003115	100.0
0.0001138	0.0007524	100.0
1.008e-006	6.663e-006	100.0

A22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Principal Component 2
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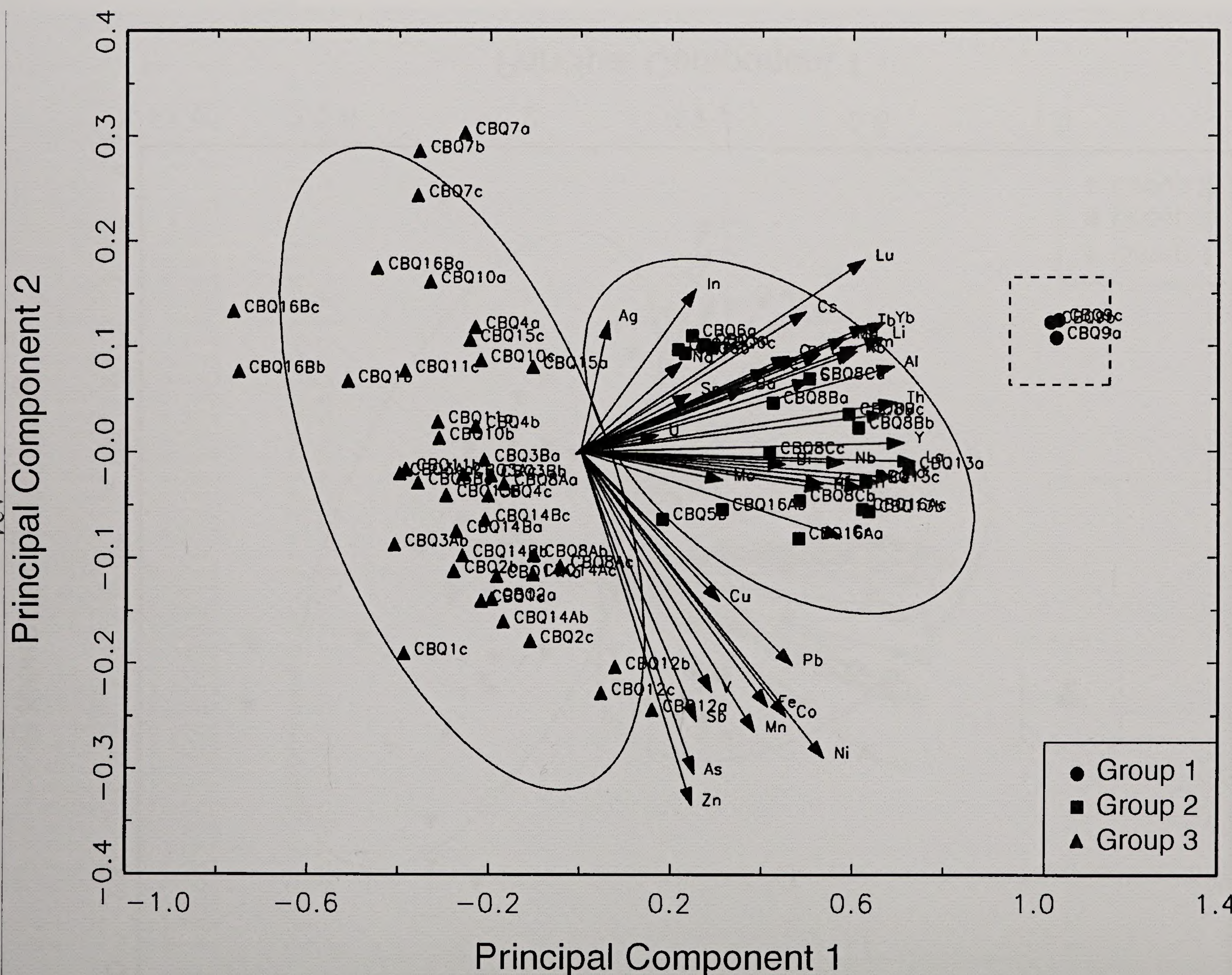
0.2
0.6
1.0
1.4
−0.4
−0.3
−0.2
−0.1
−0.0
0.1
0.2
0.3
0.4
Group 1
Group 2
Group 3
Lu
Cs
In
Ag
Al
Th
Dy
Y
La
Sr
Nb
Bi
Cr
Pb
Fe
Co
Ni
Mn
Cu
Sb
As
Zn
Nd
Mo

20


Principal Component 1
Principal Component 2
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0.2
0.6
1.0
1.4
−0.4
−0.3
−0.2
−0.1
−0.0
0.1
0.2
0.3
0.4
Group 1
Group 2
Group 3
CBQ7a
CBQ7b
CBQ7c
CBQ16Ba
CBQ10a
CBQ16Bc
CBQ16Bb
CBQ4a
CBQ15c
CBQ11c
CBQ15a
CBQ10b
CBQ4b
CBQ3Ba
CBQ4c
CBQ14Bc
CBQ14Ba
CBQ3Ab
CBQ14Ab
CBQ2c
CBQ1c
CBQ12b
CBQ12c
CBQ5b
CBQ16Ab
CBQ16Aa
CBQ8Ba
CBQ8Bb
CBQ8Cc
CBQ8Cb
CBQ13a
CBQ9a
Lu
In
Ag
Cs
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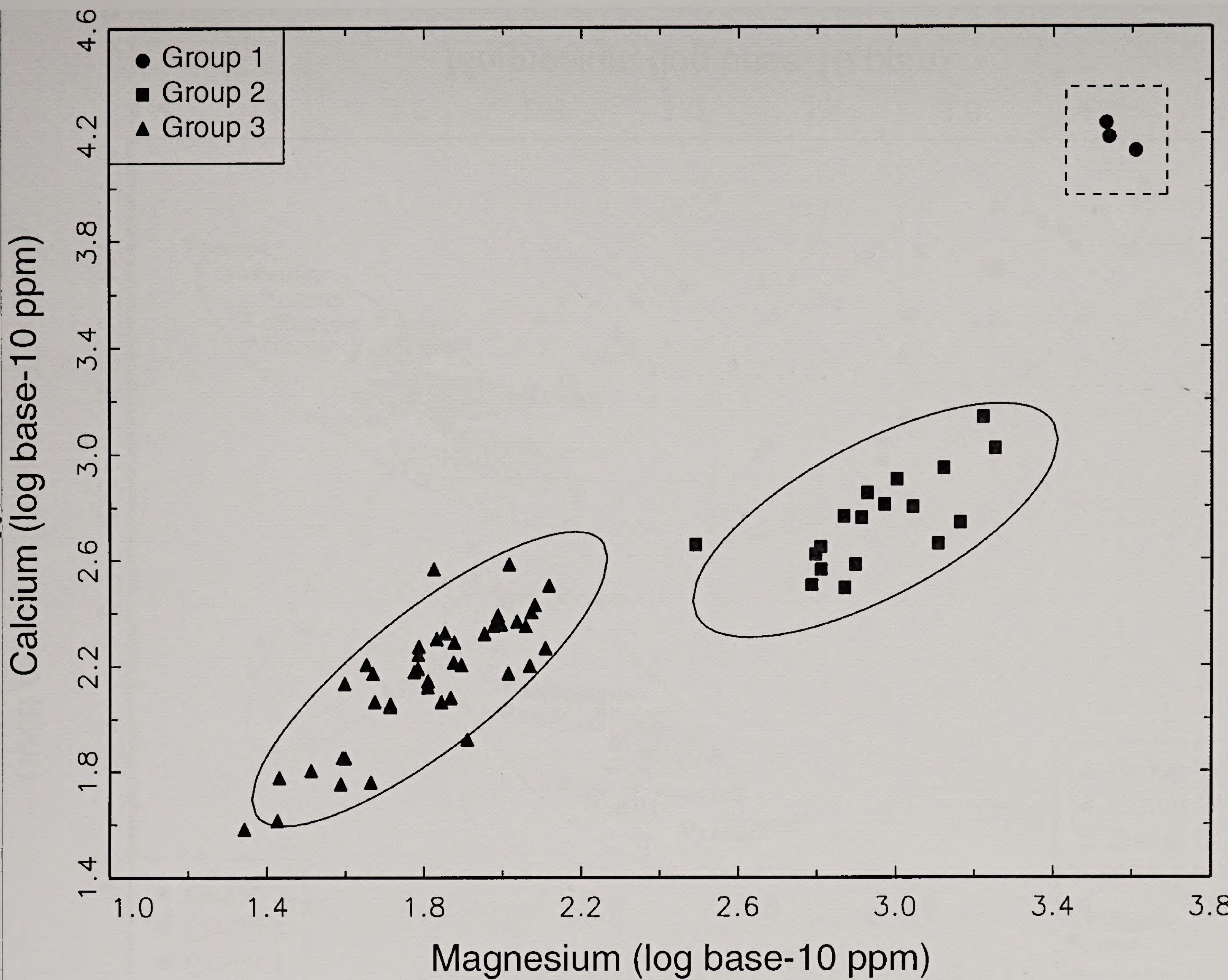
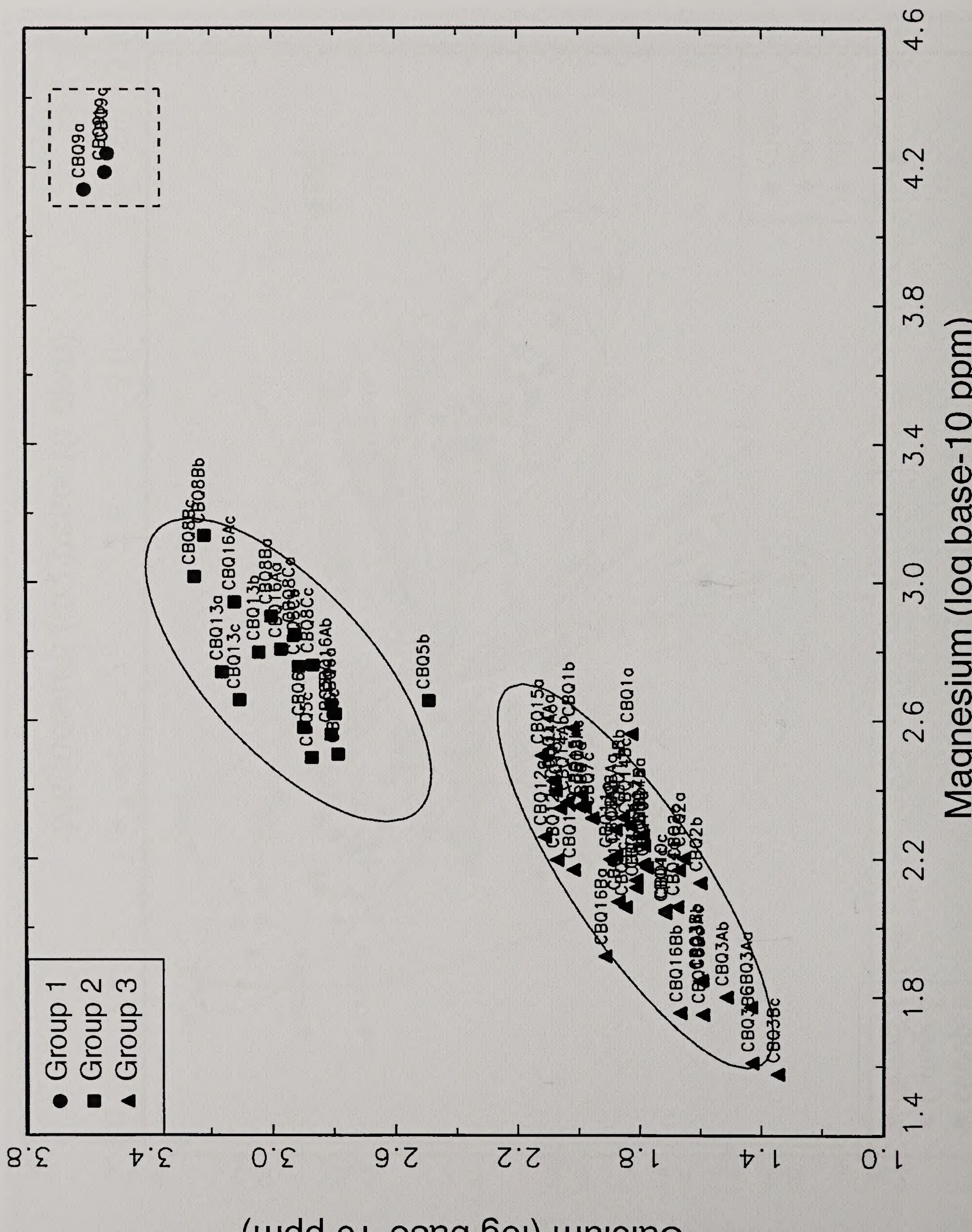
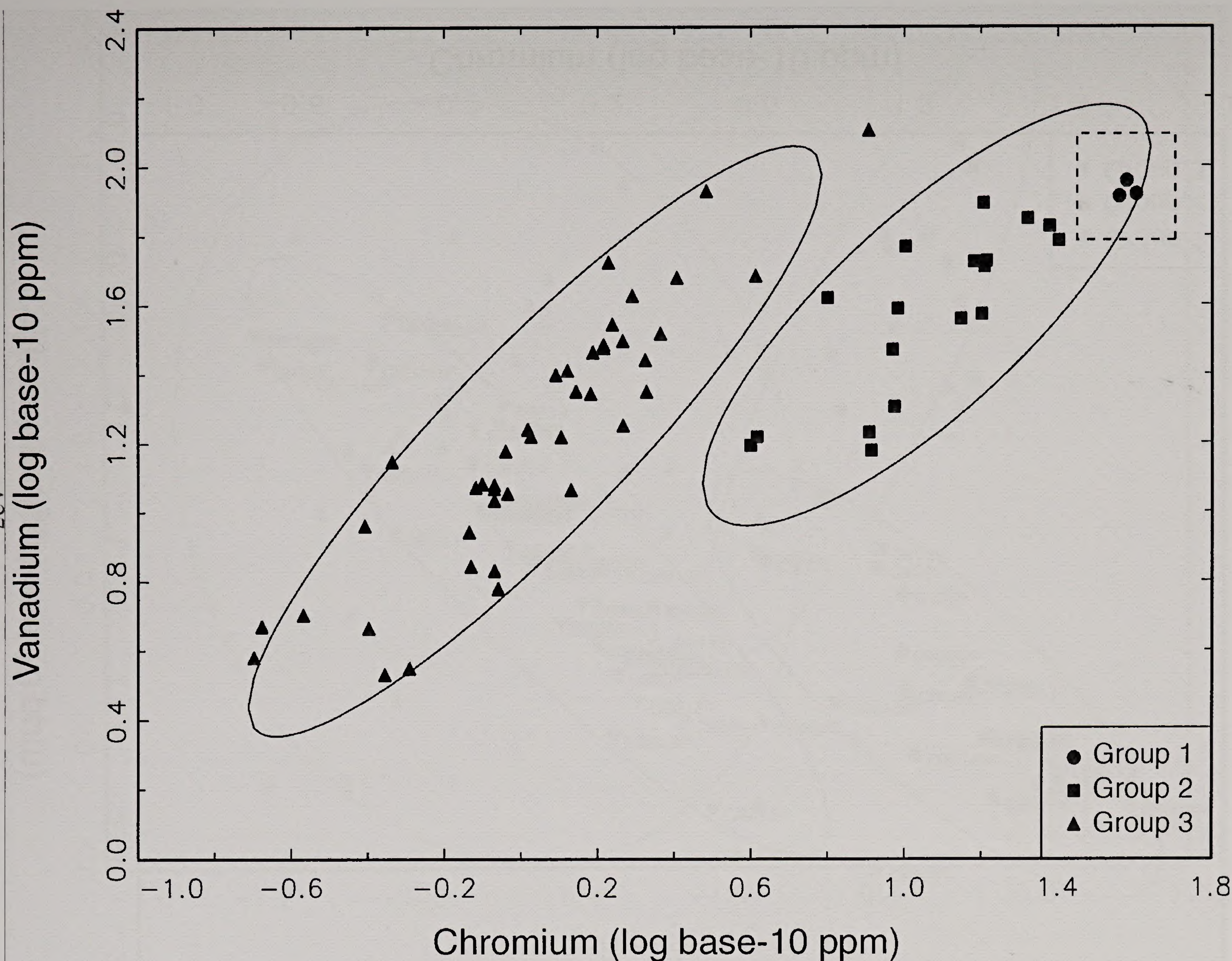

Group 1
Group 2
Group 3
Calcium (log base-10 ppm)
1.4
1.8
2.2
2.6
3.0
3.4
3.8
4.2
4.6
1.0
1.4
1.8
2.2
2.6
3.0
3.4
3.8
Magnesium (log base-10 ppm)

A25


Group 1
Group 2
Group 3
Magnesium (log base-10 ppm)
Calcium (log base-10 ppm)
1.4
1.8
2.2
2.6
3.0
3.4
3.8
4.2
4.6
1.0
1.4
1.8
2.2
2.6
3.0
3.4
3.8


Vanadium (log base-10 ppm)
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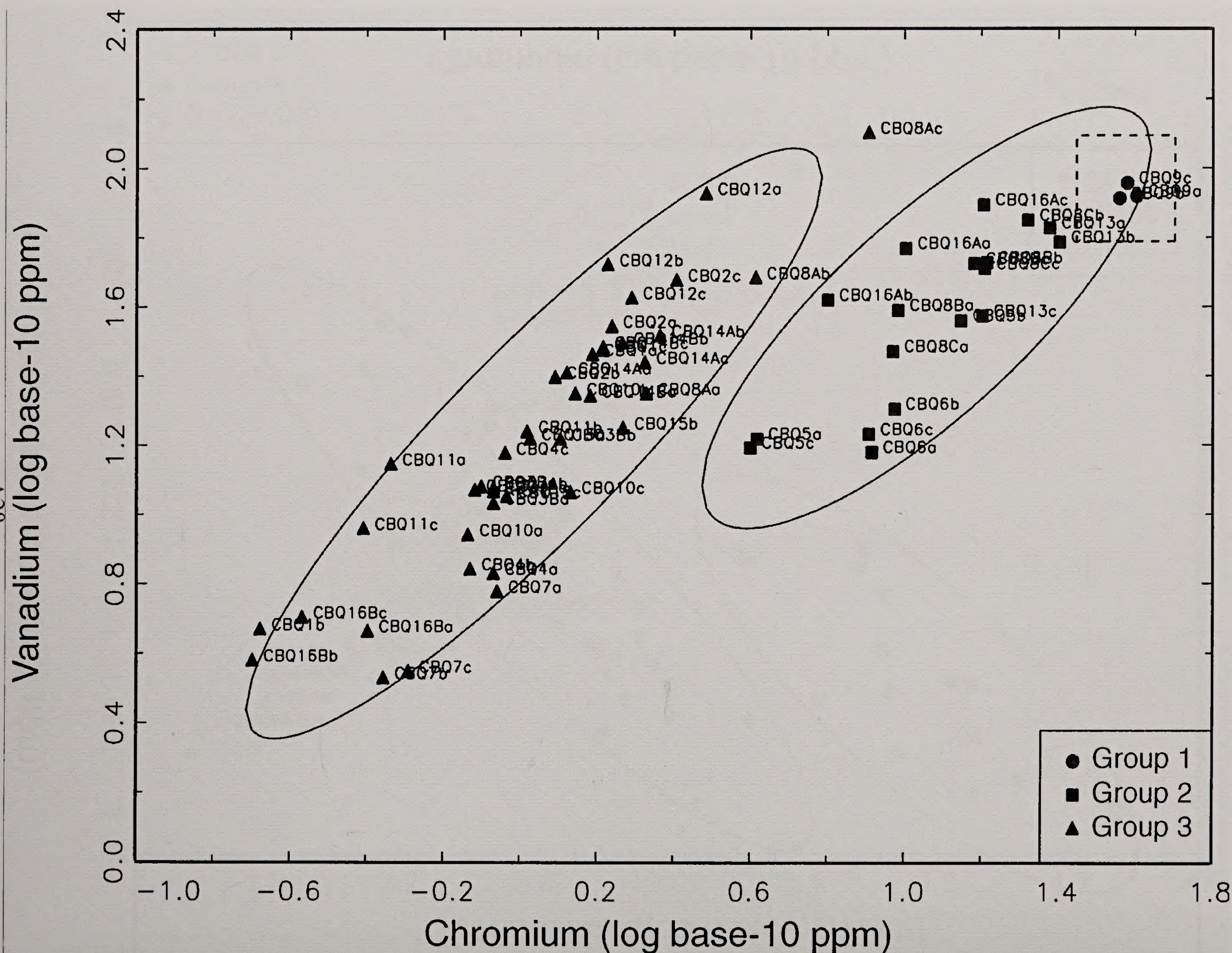
0.4
0.8
1.2
1.6
2.0
2.4
−1.0
−0.6
−0.2
0.2
0.6
1.0
1.4
1.8
Chromium (log base-10 ppm)
Group 1
Group 2
Group 3


Vanadium (log base-10 ppm)
Chromium (log base-10 ppm)
0.0
0.4
0.8
1.2
1.6
2.0
2.4
−1.0
−0.6
−0.2
0.2
0.6
1.0
1.4
1.8
Group 1
Group 2
Group 3
CBQ8Ac
CBQ12a
CBQ12b
CBQ2c
CBQ8Ab
CBQ12c
CBQ14Ab
CBQ14Ac
CBQ8Aa
CBQ15b
CBQ4c
CBQ11a
CBQ10c
CBQ11c
CBQ10a
CBQ7a
CBQ16Bc
CBQ16Ba
CBQ15Bb
CBQ7c
CBQ16Ac
CBQ13a
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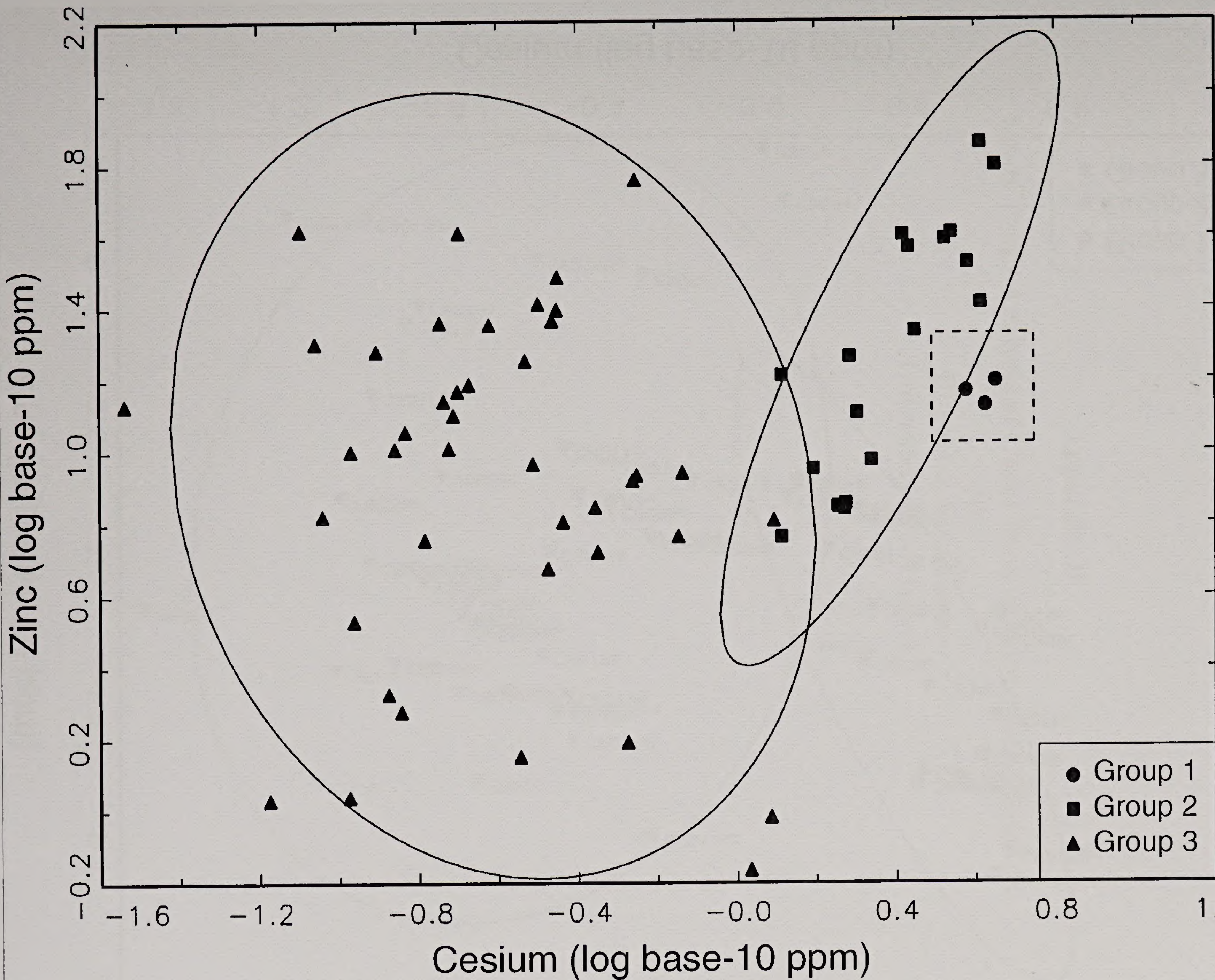
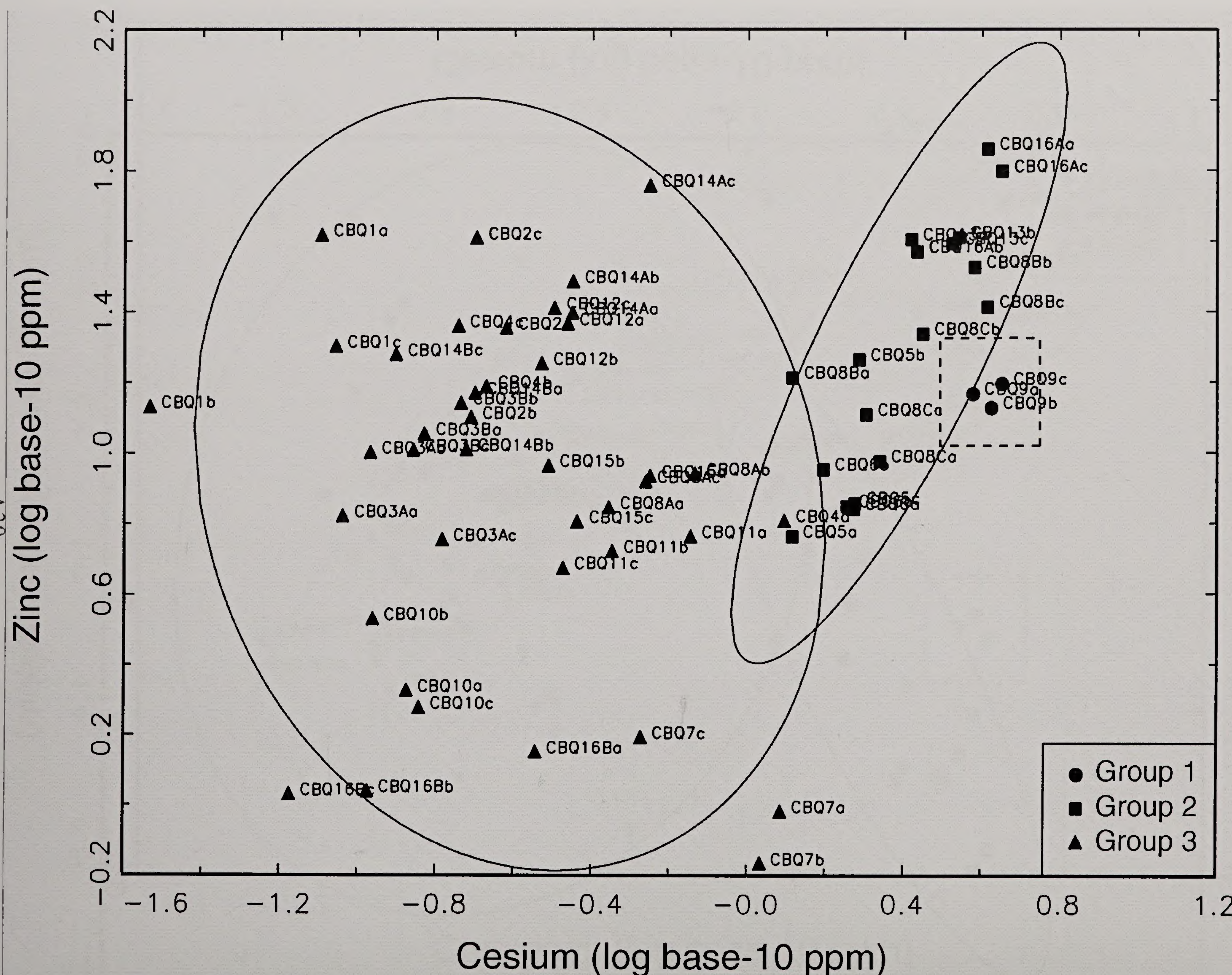
CBQ6c
CBQ9c


Zinc (log base-10 ppm)
−0.2
0.2
0.6
1.0
1.4
1.8
2.2
−1.6
−1.2
−0.8
−0.4
−0.0
0.4
0.8
1.2
Cesium (log base-10 ppm)
Group 1
Group 2
Group 3


Zinc (log base-10 ppm)
Cesium (log base-10 ppm)
−0.2
0.2
0.6
1.0
1.4
1.8
2.2
−1.6
−1.2
−0.8
−0.4
−0.0
0.4
0.8
1.2
Group 1
Group 2
Group 3
CBQ16Aa
CBQ16Ac
CBQ14Ac
CBQ1a
CBQ2c
CBQ14Ab
CBQ12a
CBQ1c
CBQ14Bc
CBQ12b
CBQ1b
CBQ2b
CBQ3Ba
CBQ14Bb
CBQ15b
CBQ8Ab
CBQ3Aa
CBQ8Aa
CBQ15c
CBQ3Ac
CBQ11a
CBQ11b
CBQ11c
CBQ10b
CBQ10a
CBQ10c
CBQ7c
CBQ16Ba
CBQ16Bb
CBQ7a
CBQ7b
CBQ8Bb
CBQ8Bc
CBQ8Cb
CBQ5b
CBQ8Ba
CBQ9c
CBQ9b
CBQ8Ca
CBQ4a
CBQ5a

Appendix B

LA-ICP-MS Analysis of Chert from Southwestern Montana

By

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University of Missouri-Columbia

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February 17, 2003

Dr. Tom Roll Department of Sociology and Anthropology Montana State University Bozeman, MT 59717–2380

Dear Tom:

Enclosed are five figures that illustrate the data structure determined for the chert samples you submitted for LA-ICP-MS last July and November. An Excel spreadsheet containing the raw data (expressed as parts-per-million oxide) is also included. The analytical procedures are identical to those discussed in our November 2002 report and are not repeated here.

In our November 2002 report we discussed how we were hampered somewhat by a relatively small sample size (n=16). In order to inflate the sample size, each specimen was analyzed at three discrete locations. Rather than average the data obtained from the three locations, each analysis at each loci was treated as a separate sample. This permitted the sample size to be increased from 16 to 48 and permitted variation within samples to be observed (see Figures 2, 4, 6, and 8 in the November 2002 report). Additionally, samples CBQ3, 14, and 16 contained two distinct colors/structures and sample CBQ8 contained three distinct colors/ structures within the sample. In these cases, each distinct color/structure was also analyzed at three discrete locations. This resulted in a combined total of 63 analyses which facilitated the use of multivariate statistics and permitted group membership to be tested through the use of Mahalanobis distance-based probabilities.

With the submission of the 38 new samples, we determined that we could average the replicate data from the original study and still have a sample size that would permit principal components analyses to be performed. Therefore data generated for the original study were averaged. This reduced the number of *specimens* from 63 to 21. The different colors/structures for CBQ3, 8, 14, and 16 are represented individually. Each of the new 38 samples was scanned three times at two discrete locations and averaged. Additionally, two samples, CBQ1 and CBQ4, were reanalyzed. The reason for this was to ensure that data generated for the July and November analyses were comparable. In total, 61 analyses are represented in Figures 1–5 and the attached spreadsheet—21 from the original study, 38 from the second submission of samples, and two replicates.

Figure 1 is a PCA biplot of principal components 1 and 2. Principal component 2 expresses enrichment of calcium, strontium, magnesium, and manganese, and dilution of silicon. Principal component 1 expresses enrichment of lanthanides and transition metals. Figure 2–4 show several projections of the data in bivariate space.

Membership in Camp Baker-1 and Camp Baker-2 (originally Group 1 and Group 2) has not changed from the original report.

The undifferentiated group (originally Group 3) contains the same specimens as originally reported plus samples from Doggett Quarry and the unnamed Meagher County Quarry. The chemical similarity between the three quarries was not unexpected due to their proximity to one another. However, the samples from Devil's Eyebrow Quarry and the four brown chert samples from Logan Quarry also have membership in this group. It is unfortunate that samples from these quarries are chemically the same; this has been a major problem with chemical-based studies of chert.

On the positive side, the two gray samples from Logan Quarry consistently group together and are clearly different from all other groups. The three samples from Lime Creek Quarry are unique in that they have elevated phosphorous levels. The four samples from Avon Quarry are likewise distinct from all other sources. Finally, the South Everson Quarry samples form a seventh distinct compositional group. With the exception of the undifferentiated group, all groups are relatively small. Future research should focus on refining the Logan Gray, Avon, and Lime Creek Quarry samples.

One analytical concern with LA-ICP-MS is that instrument settings are changed daily in order to optimize the instrument. Settings that vary slightly, even during a brief period of time such as a few days or weeks, may affect the mass bias of the instrument. This has the potential to create artificial groups or mask real groups thus making data from two analyses difficult or impossible to compare. In order to ensure that mass bias had no effect (or an insignificant effect) on the data, two replicates originally analyzed in July 2002 were reanalyzed in November 2002. Figure 5, a bivariate plot of aluminum and uranium base-10 logged-oxide concentrations indicates the replicates are virtually identical to the original analyses. These data serve to alleviate any concerns about the fact that the data were generated several months apart.

Mike Glascock and I believe these data will make a nice presentation at the SAA's given that the success of this project was better than most chert projects. We ask that you acknowledge on the poster that purchase of the laser ablation system and ICP-MS was funded, in part, by a grant from the National Science Foundation (SBR-9977237). We are also interested in seeing these data published and thought that perhaps *Archaeology in Montana* might be an appropriate venue. Alternatively, I am in the process of putting together an edited volume on LA-ICP-MS (with Hector Neff) for the University of New Mexico Press. If you are willing, I would be happy to include a chapter on the chert. However, we are trying to get all the chapters together by the end of March so that we can submit the final manuscript in June. I realize that this may not give you much time to write a paper and understand if you and Mike Neely are unable to contribute a paper to the volume.

On another note, we were happy to receive the porcelanite and NVG samples. Our students are busy preparing them for irradiation and we should have data generated for them in three to four months. I have assigned the prefix PNV (for porcelanite/nonvolcanic glass) followed by a three digit number and will provide a spreadsheet with the descriptive information and ID's in the near future. Should you have the opportunity to collect more NVG source samples Mike and I would be happy to analyze them. If we determine the different porcelanite and NVG sources are unique, we may also solicit a few artifacts for analysis.

An invoice for the analyses of these chert samples is included. The amount is $950.00 (38 x $25/ea). Please let me know if you have any questions or need additional copies or changes made to the figures for the SAA poster.

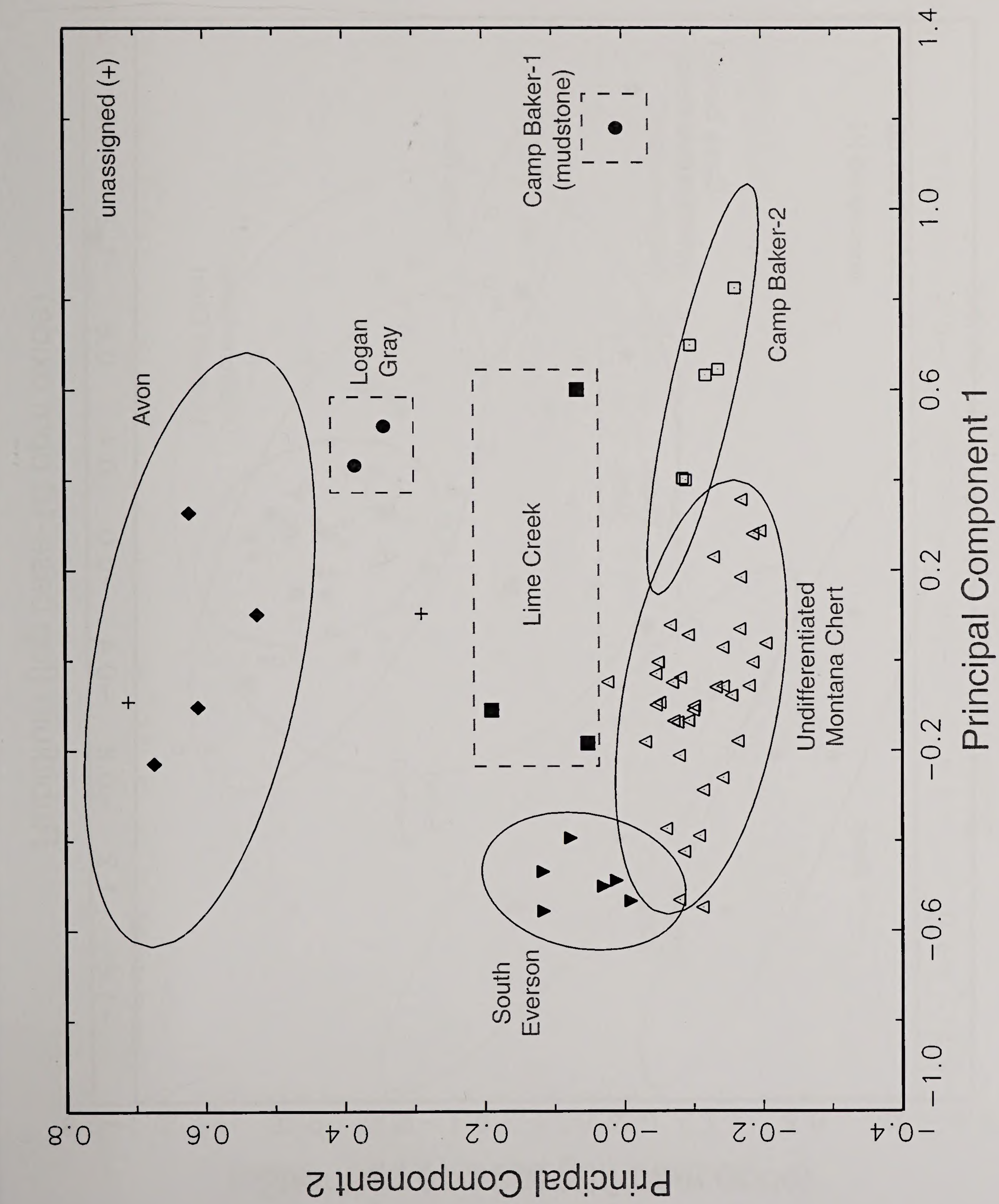
Best regards,

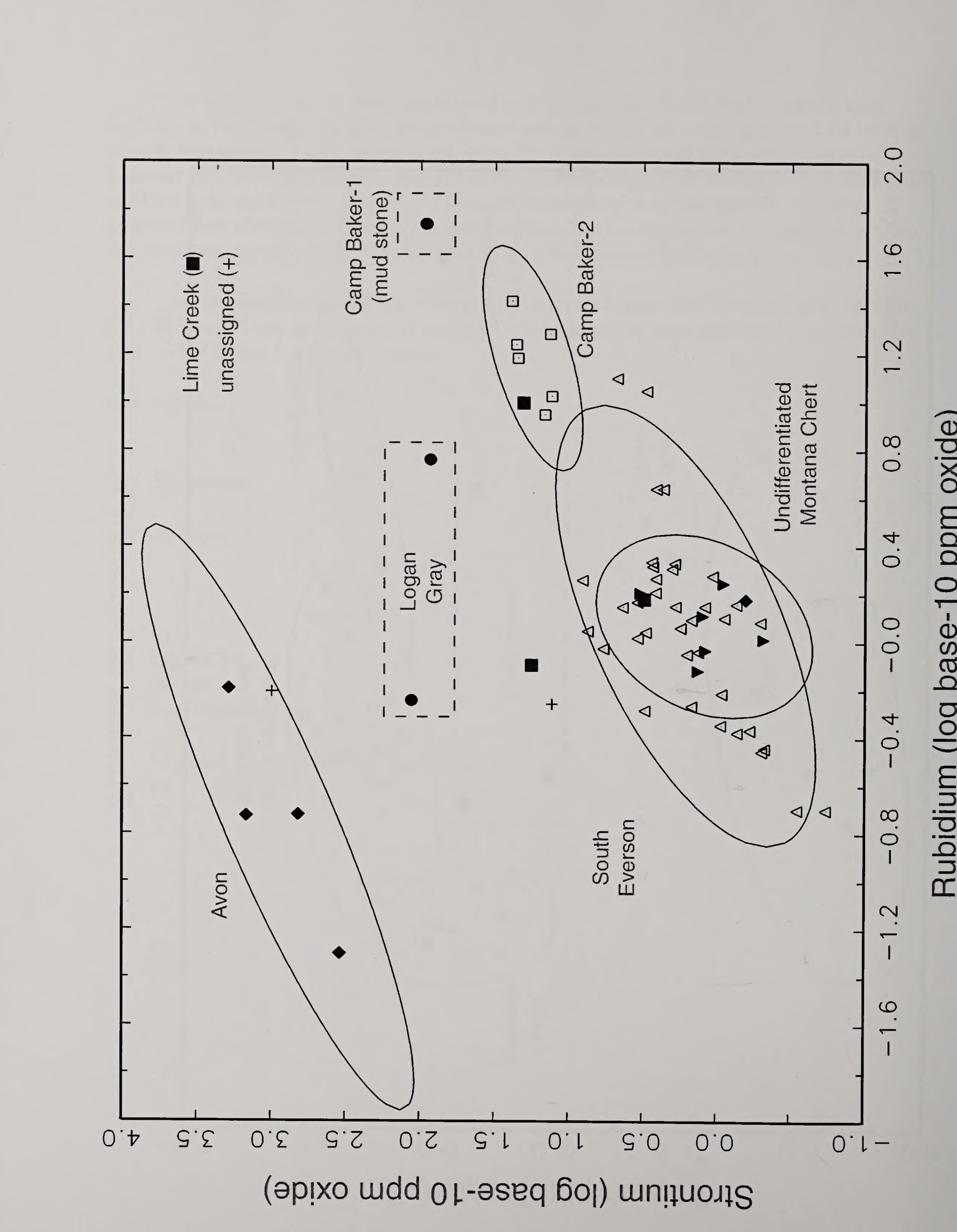
Jeff Speakman

Jeff Speakman

Enc: Figures 1-5
Invoice
Excel Spreadsheet

An Equal Opportunity/ADA Institution


Avon
Logan Gray
Lime Creek
unassigned (+)
Camp Baker-1 (mudstone)
Camp Baker-2
South Everson
Undifferentiated Montana Chert
Principal Component 1
Principal Component 2
−1.0
−0.6
−0.2
0.2
0.6
1.0
1.4
−0.4
−0.2
−0.0
0.2
0.4
0.6
0.8


Avon
Logan Gray
Lime Creek (■)
unassigned (+)
Camp Baker-1 (mud stone)
Camp Baker-2
Undifferentiated Montana Chert
South Everson
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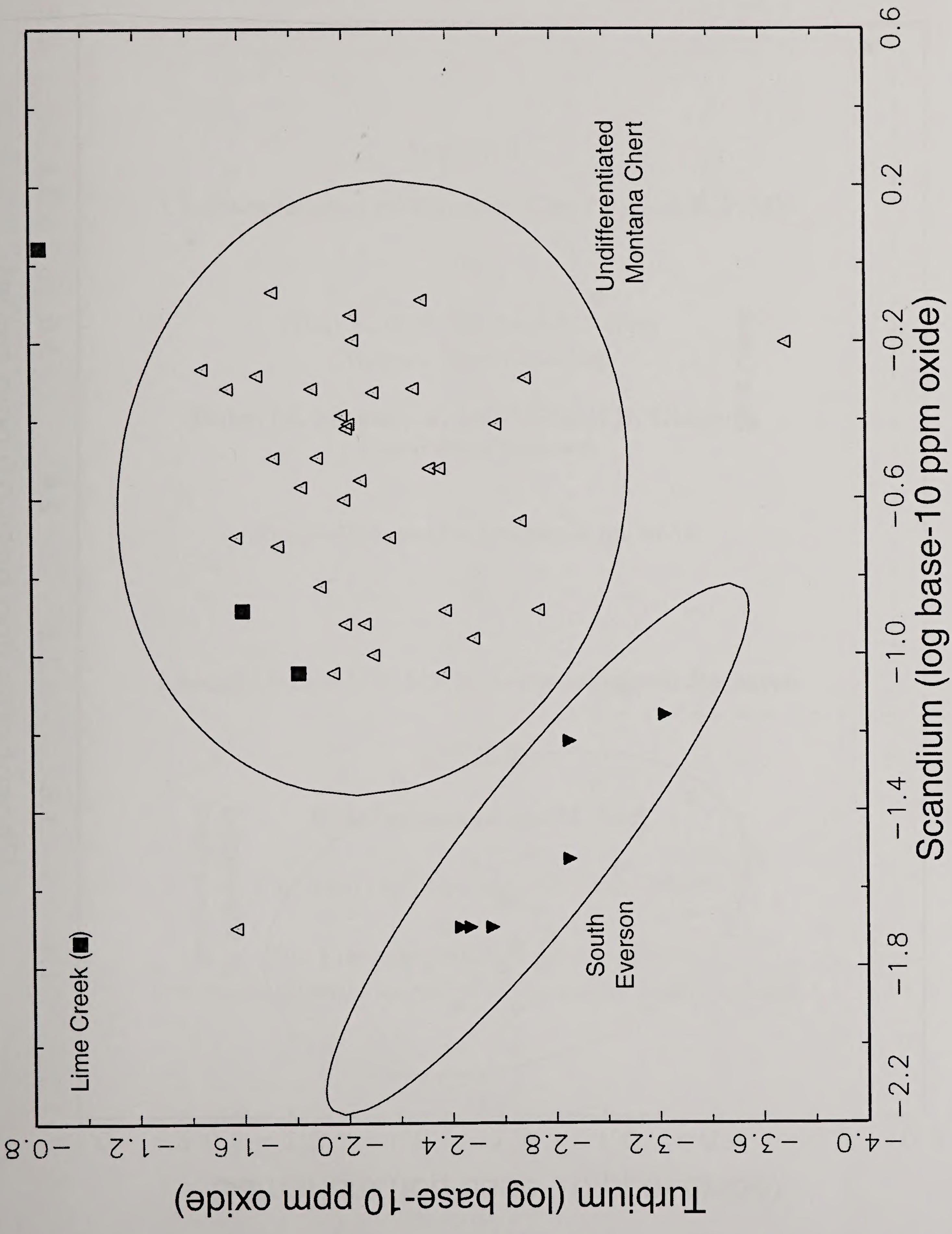
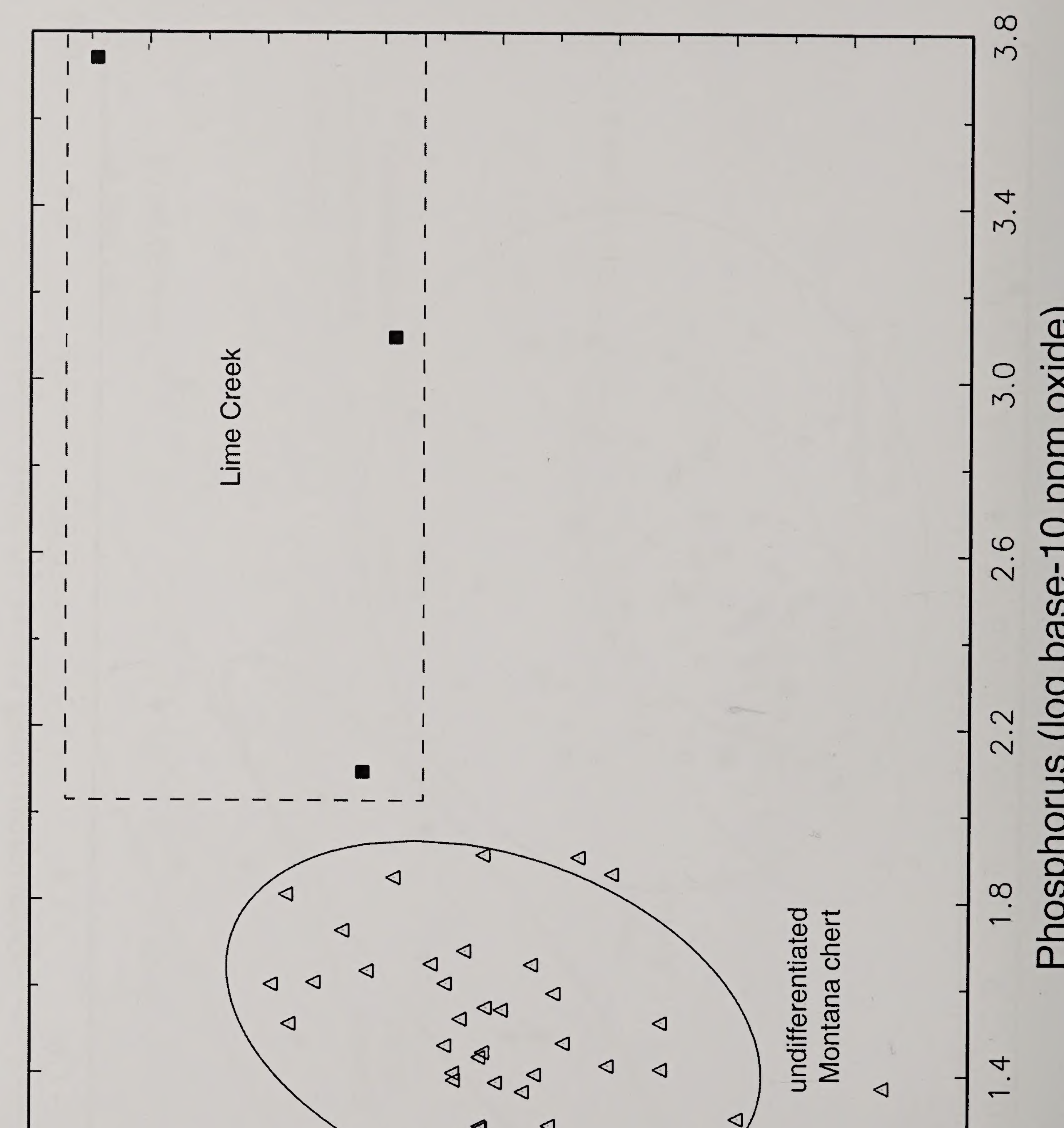
Strontium (log base-10 ppm oxide)


Lime Creek
South Everson
Undifferentiated Montana Chert
Scandium (log base-10 ppm oxide)
−2.2
−1.8
−1.4
−1.0
−0.6
−0.2
0.2
0.6
Turbium (log base-10 ppm oxide)
−4.0
−3.6
−3.2
−2.8
−2.4
−2.0
−1.6
−1.2
−0.8



Lime Creek
undifferentiated
Montana chert
Phosphorus (log base-10 ppm oxide)
Samarium (log base-10 ppm oxide)
1.0
1.4
1.8
2.2
2.6
3.0
3.4
3.8
−3.0
−2.6
−2.2
−1.8
−1.4
−1.0
−0.6
−0.2
0.2

Appendix C

Characterization of Montana Chert by LA-ICP-MS

By

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Chapter 5: Characterization of Montana Chert by LA-ICP-MS

Tom E. Roll, Michael P. Neeley, Robert J. Speakman, and Michael D. Glascock

This discussion briefly addresses the distribution of lithic resources throughout Montana, with particular emphasis on chert and its identification (Luedtke 1992). The application of laser ablation-inductively coupled plasma- mass spectrometry (LA-ICP-MS) to chert samples from a limited set of prehistoric quarries in southwestern Montana figures prominently in this discussion. This research was undertaken with the express purpose of evaluating the potential of this analytical technique to identify chert from a particular quarry, locality, geologic formation, and/or physiographic region. Despite the ability to detect a wide range of trace elements at extremely low levels, the analyses produced somewhat equivocal results. Of the eight quarries sampled, three quarries in the Smith River area, one quarry in the Gallatin Valley and one quarry in the Flint Creek Valley yielded essentially indistinguishable elemental composition. More accurately, the range of variation within a single quarry overlapped substantially with the range of variation in the other quarries. Three quarries, the Avon Quarry in the Avon Valley, the South Everson Quarry in the Beaverhead Valley, and the Lime Creek North Quarry in the upper Gallatin Valley yielded signatures different from each other and from the other quarries sampled (Figure 1).

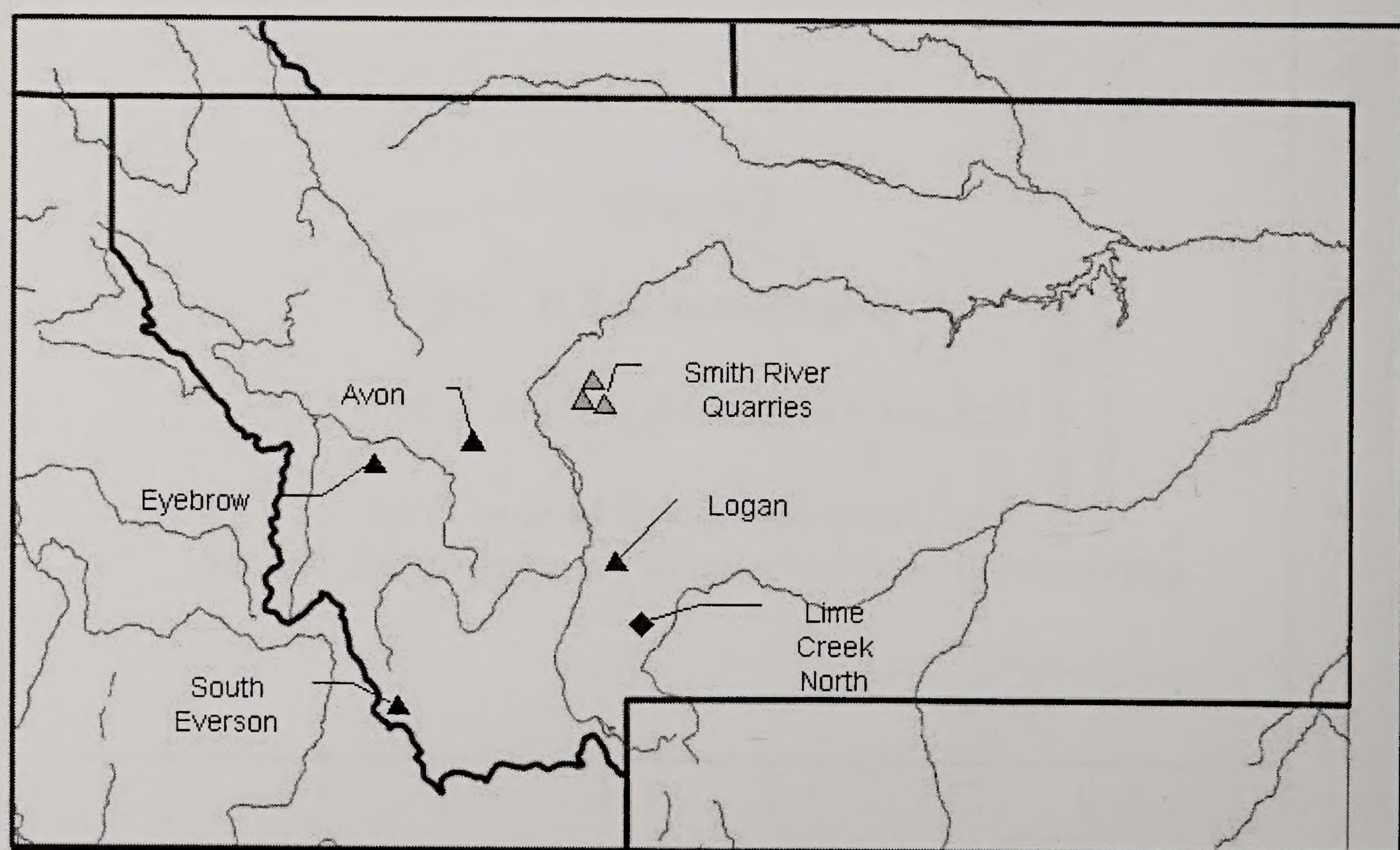

Figure 1. Map of the project area showing the quarry locations sampled in this project.

Identifying Lithic Sources

Under some circumstances, visual examination may permit archaeologists to reliably attribute lithic materials to their source. On the other hand, the assumptions implicit in such identifications are rarely considered in detail. Visual identification of stone sources often depends upon unwarranted assumptions about the distribution of explôited stones. Frequently, sources distributed over substantial geographic distance exhibit extensive overlap in visual attributes. Even sources originating in different geological formations, either in terms of their formation processes or chronology, may share identical visual characteristics. Initially, attribution of archaeological stone tools to source seems straightforward. However, as knowledge of the actual distribution of sources, and as the variability within and between sources becomes apparent, confidence in the reliability of visual characteristics decreases. The archaeologist faced with the job of classifying thousands of pieces of debitage needs to utilize analytical techniques commensurate with the time and resource constraints. For the foreseeable future, that archaeologist must rely on visual identification of lithic types. Ideally, instrumental techniques will promote the development of more reliable visual techniques for source attribution and/or an increased awareness of the hazards of such identification.

Despite the importance of lithic source identification, chemistry-based methods for identifying sources have eluded archaeologists until relatively recently. Early success in separating obsidian sources used a number of techniques for determining elemental composition (cf. Griffin et al. 1969:2). Today, X-ray fluorescence (XRF) and instrumental neutron activation analysis (INAA) dominate as the principal techniques for source identification. Although INAA has the ability to measure trace elements at lower levels, XRF has emerged as one of the primary analytical tools of choice (at least in North America) for characterization of igneous rocks such as obsidian, basalt, and dacite because of its relatively low cost, and non-destructive nature. These analytical techniques and others have demonstrated their usefulness in a number of other archeological applications, particularly for ceramics and metals. The development of analytical techniques that permit similar source identification of chert has proven remarkably difficult, in part because of the complexities of dealing with the comparatively limited compositional variation that occurs in chert (cf. Luedtke 1992).

The measurement of various elements present in chert has been used to determine chemical fingerprints in chert provenance studies. Chert is far less homogeneous than obsidian, and any attempt to match an artifact with its source can be successful only if the differences between sources are greater than the variability within each source. In general, the differences between major oxides as determined by classical methods (e.g., microprobe analysis, XRF) are insufficient for identifying differences between similar chert types. As a result, measurements of the amounts of minor or trace elements present in chert are frequently being studied to identify the sorts of differences required for provenance determination. Only a handful of chemical studies of chert have met with success (Aspinall et al. 1975; Bush and Sieveking 1983; Hoard et al. 1992, 1993; Julig et al. 1988; Lyons et al. 2003; McGinley and Schweikert 1979; Speakman et al. 2001, 2002).

One limitation that hampers chemistry-based chert provenance studies is the heterogeneous nature of chert. INAA is by far the most popular of the available analytical methods. However, several major drawbacks of INAA exist—namely that artifacts must be

destroyed in order to analyze them and the high analytical cost. Alternatively, LA-ICP-MS is an analytical technique that is rapidly growing in popularity for chert characterization studies (e.g., Blet-Lemarquand 1999; Gratuze et al. 2001; Rockman et al. 2003; Speakman et al. 2001, 2002). Although this method provides a means for generating chemical data for most elements on the periodic table, we must keep in mind that LA-ICP-MS is a "spot" analytical technique, rather than a bulk analytical technique. Consequently, if a chert is chemically heterogeneous, it may be difficult to accurately characterize. Fortunately, this did not appear to be the circumstance in our study.

Lithic Resources in Montana

Many areas of Montana possess multiple sources of relatively high-quality lithic material suitable for stone tool manufacture. Throughout much of the state, acquisition of usable stone for tool manufacture rarely requires a journey of more than 100 km. A recent search of the Montana statewide files identified 655 prehistoric sites characterized by lithic raw material procurement as the principal activity or a prominent associated activity (many site reports identify multiple site functions). These records revealed 163 "bedrock quarries" and 492 "surface stone quarries." Lithic sources represent a prominent cultural resource, particularly if one considers the size of Montana, the difficulty of locating archaeological materials in the heavily forested, mountainous western portion of the state, and the relatively limited coverage by archaeological reconnaissance.

Our research has stressed analysis of chert from selected quarries in the southwest quadrant of Montana. This part of Montana represents a remarkably complex geologic history. Southward out of Alberta, Canada, the eastern margin of the Fold-Thrust Belt roughly parallels the Rocky Mountain crest until it meets the northern slopes of the Big Belt Mountains between Great Falls and Helena, Montana. The Fold-Thrust Belt extends southeastward in a sinuous fashion to include the Big Belts. Along the southern foothills of the Big Belts, the Fold-Thrust Belt curves southwestward toward the canyon of the Jefferson River, and continues west of the Jefferson along the lower slopes of the Pioneer and Tendoy mountains where it curves eastward again and strikes the Continental Divide at Monida Pass (Figure 2).

The Lewis and Clark Line, a "major and long-lived intraplate tectonic boundary," (Reynolds and Kleinkopf 1977:1141) roughly parallels the Clark Fork River Valley from Kellogg, Idaho, east toward the Continental divide, crosses the divide in the vicinity of Helena, Montana, and continues beyond the Big Belt Mountains. This tectonic feature divides the Fold-Thrust Belt into northern and southern segments. In the North Fold-Thrust Belt, Precambrian Belt Series rocks dominate the lithic sphere and relatively few good chert sources exist. The South Fold-Thrust Belt has numerous exposures of Phanerozoic sediments ranging in age from early Paleozoic to Quaternary and has been heavily influenced by the intrusion of the Idaho and Boulder batholiths. This assortment of sediments has resulted in a diverse set of potential chert-bearing rocks. Chert from three quarries located in this area were analyzed as part of this project. The remaining five quarries lie in the Forelands tectonic province that formed the remainder of mountainous southwestern Montana and extends along the eastern edge of the South Fold-Thrust Belt to the east slope of the Big Horn Mountains on the Wyoming/Montana border.

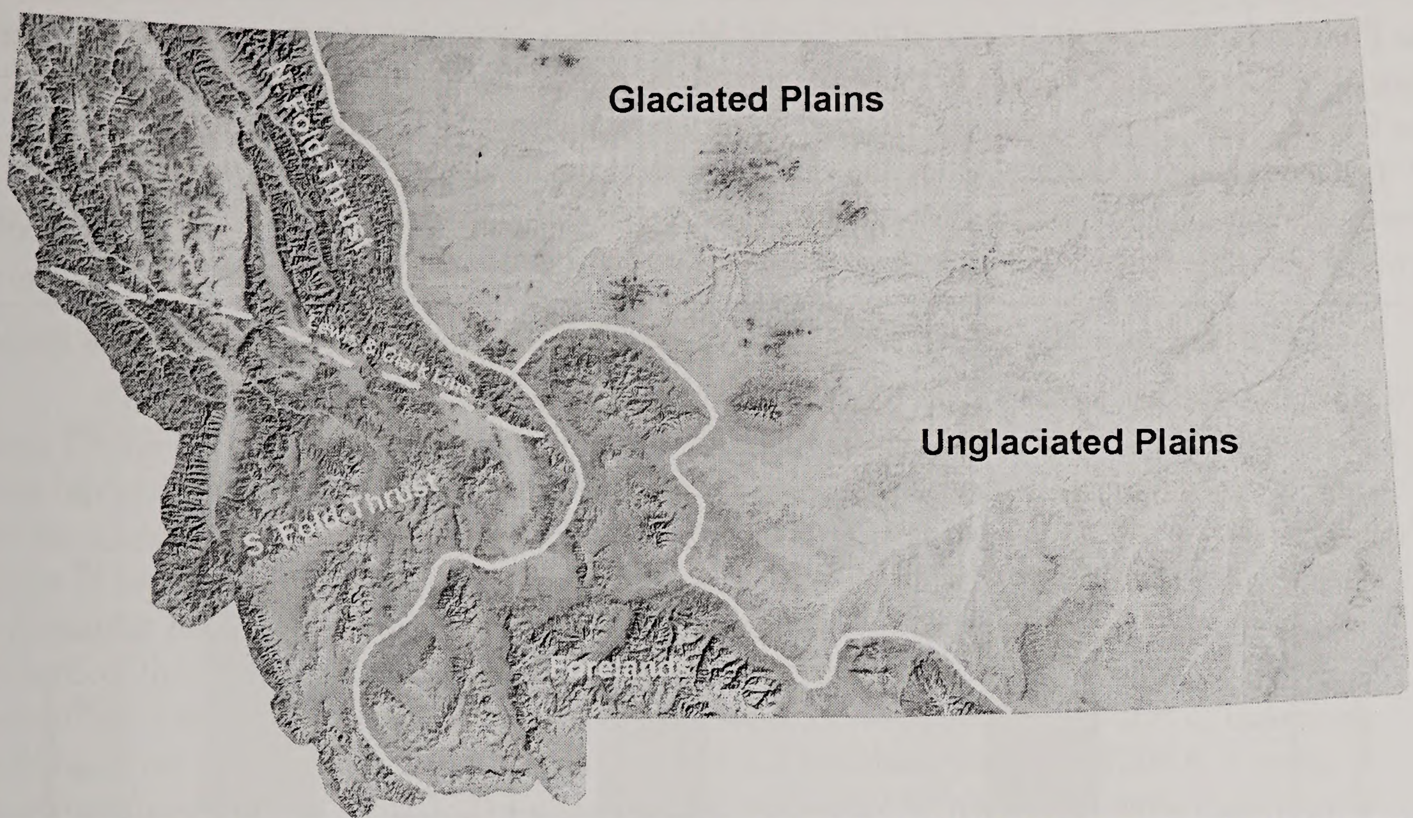

Figure 2. Map of the project area showing the major geologic zones discussed in the text.

When normed for size, the South Fold-Thrust and the Forelands contain approximately equal numbers of identified bedrock and surface stone quarries. In fact, with the exception of low frequencies of bedrock quarries in the Plains and North-Fold Thrust region, when normed for area, the frequency of quarries remains nearly constant throughout the state. However, the ratio of quarries to other site types varies dramatically. Southwestern Montana possesses approximately three times the number of quarries per 1000 sites as the rest of the state (Table 1, Figure 3). For the remaining 75% of Montana, bedrock quarries account for 3.3 out of every 1000 sites while surface stone quarries make up about 12.6 per 1000.

In terms of high-quality lithic resources for stone tool manufacture, the South Fold-Thrust Belt and the neighboring Forelands share much in common. Prominent chert sources in the South Fold-Thrust Belt include the Avon Quarries (Cameron 1984; Fields 1983), the Eyebrow Quarry (McLeod and Melton 1986), the California Creek Quarry (Davis et al. 1988), and the South Everson Creek Chert Quarry (MacWilliams 1990, Bonnichsen et al. 1992; Davis et al. 1997). the Palmer Chert Quarry (Herbort 1990) , one of a cluster of quarries in the vicinity of Montana City, southeast of Helena, Montana, and numerous less well-known quarries. Knudson's (1973:129–132) behavioral model of Paleo-Indian activity at MacHaffie II (the post-Folsom level) attributes procurement and reduction of lithic materials as a prominent focus. One or more of the quarries in the Montana City cluster likely provided the raw material used by the prehistoric inhabitants of the MacHaffie Site.

Many prominent primary sources of chert and fine-grained quartzite in Montana lie in the Forelands. Along both slopes of the Rocky Mountains a surprising number of chert quarries exist. The more widely known of these include the Schmitt Chert Mine (Davis, et al. 1978), the Garnet Peak Quarries, and the Doggett Quarry (Bonnichsen 1977) about 10 miles south of the Camp Baker Quarries. Along the eastern edge of the Forelands Province, both the Big Horns Mountains and the Pryor Mountains possess substantial quantities of both chert and fine-grained quartzite suitable for stone tool manufacture (cf. Loendorf 1969; 1971; 1973; 1974).

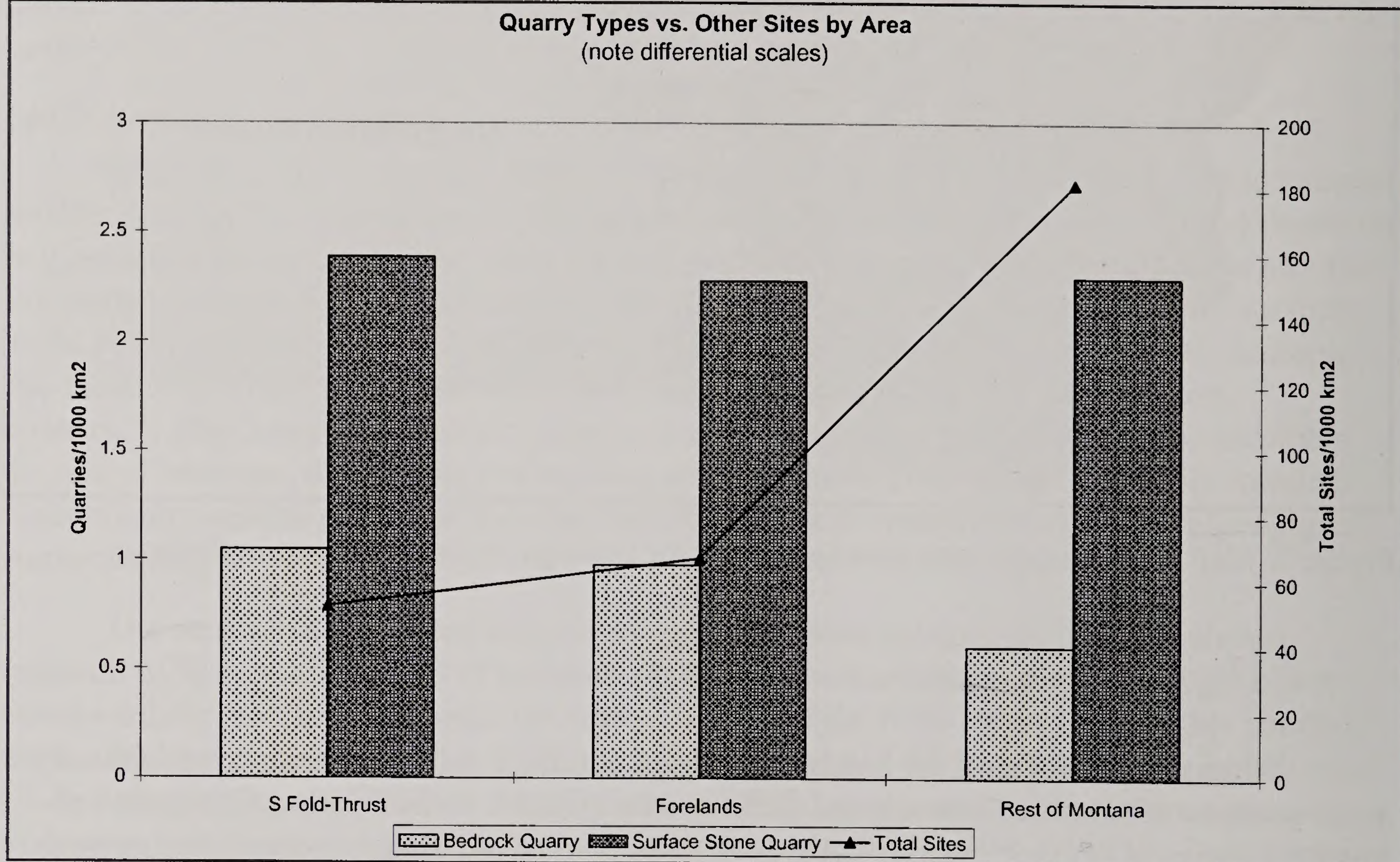

Figure 3. Comparison of Montana quarry types by size and geologic location.

Table 1. Ratios of quarry types per 1000 sites (normed for area).

Region	Bedrock Quarries	Surface Stone Quarries	All Quarries
S Fold-Thrust	20.0	45.4	65.5
Forelands	14.5	33.9	48.5
Remainder of Montana	3.3	12.6	16.0

Geologically, cherts found in the Rocky Mountain uplift zone originate in sediments that vary widely in age. The various Smith River Quarries (in particular Camp Baker and Doggett) and the Eyebrow Quarry contain rocks apparently developed in Cambrian age sediments. Many, but by no means all, chert found in a broad band extending north and south along the Upper Missouri River and its headwaters formed in sediments of Late Paleozoic age, probably both Devonian and Mississippian. Investigators attribute the formation of chert at both the Avon Quarry (Fields 1983) and South Everson (Bonnichsen et al. 1992; MacWilliams 1990) to silica replacement of Tertiary age sediments. In all probability, the silicification processes that created

the chert, post-date the sediments in which they formed, involved multiple events, and required substantial time. We must also consider the possibility that the silica replacement processes occurred as a roughly coeval event(s) throughout much of southwestern Montana. Clearly, the processes involved in the production of microcrystalline and or cryptocrystalline silica rocks remain difficult to specify.

Smith River Corridor—Camp Baker (24ME467), Doggett (24ME69), and 24ME332

A cooperative agreement between the Bureau of Land Management (BLM) and Montana State University (MSU) to conduct cultural resource investigations on selected BLM properties west of the Smith River in west-central Montana provided the impetus and part of the funding for this undertaking. Initially, work focused on the Camp Baker Quarry (Aaberg 1983), located about 36 km northwest of White Sulphur Springs, Montana. Fieldwork consisted of detailed topographic mapping of the site and test excavation in two of the more than 60 quarry pits identified. Subsequent work consisted of surface reconnaissance of the surrounding BLM properties. That reconnaissance disclosed the presence of discontinuous centers of quarrying activity to the southwest of Camp Baker for about 3.5 km along the 4800–5200 ft. contour. A large unnamed quarry (24ME332) containing approximately 35 pits, some more than 15 m in diameter and several meters deep, apparently represents the westernmost extent of quarrying along a silicified zone (discussed below). BLM sponsored survey resulted in the identification of less developed quarry locations extending at least 10 km to the northeast. This zone of silicification may continue even further into unsurveyed terrain. Another large quarry, the Doggett Quarry (24ME69), lies some 14 km south of Camp Baker; these two quarries exhibit about the same level of intensive use.

All of the Smith River quarries contain chert with a wide range of visible characteristics. Colors vary widely, including black, white, gray, red, and blue tones, but buff, tan, and brown colored chert are predominant. Translucence of chert from these quarries ranges from opaque to clear, with opaque or slightly translucent varieties being most common. Brecciation, resilicification, and dendritic inclusions are common. Luster ranges from shiny or waxy to dull or "earthy." Texture seems to vary according to the extent of silicification with some specimens providing a very smooth appearance whereas samples with less complete silicification resemble coarse sedimentary quartzite. In many instances, a single piece may contain multiple colors, extreme brecciation on one portion and none on another, completely opaque and clear portions, and other multiple attributes.

Current USGS or Montana Bureau of Mines and Geology geologic maps do not exist for the area. Most available geologic information for the Smith River corridor comes from M.S. thesis research conducted by Hruska (1967) in the vicinity of Camp Baker and 24ME332. The Camp Baker Quarry lies near the contact of an extrusion of Tertiary hypabyssal rocks and Cambrian age Park Shale. Pilgrim Limestone (penultimate Cambrian) conformably overlies the Park Shale a short distance upslope from the Camp Baker Quarry. Jefferson Dolomite (Devonian) outcrops in the vicinity of 24ME332 and appears as the only exposed bedrock within some distance of the site. Hruska (1967:80) identified a silicified zone that includes 24ME332 at its western extent and Camp Baker near the observed eastern margin. Given that the Smith River

served as the eastern boundary of Hruska's study area, he did not comment as to whether or not the silicified zone continues eastward. The discovery of several additional chert quarries on the east side of the Smith River suggests additional areas affected by silicification. Hruska argues that the silicified zone probably emanated from events associated with tertiary age plutonism, because he found silicified sedimentary rock dating to the Tertiary in the same zone. Regardless of the associated geologic stratum, chert from different Smith River quarries resemble each other visually, or at least, exhibit overlapping characteristics.

Excavations in 2001 disclosed only minute quantities of bone and charcoal—all of which was from uncertain contexts. These factors precluded radiocarbon dating as a mechanism for determining site age. A single small side-notched projectile point, typical of the Late Prehistoric Period (A.D. 200–1600) of the Northwestern Plains provides the only potential chronological marker directly associated with the site. Larry Lahren (personal communication, July 2003) has expressed the opinion that the Doggett Quarry provided approximately 50% of the raw material used to manufacture the stone artifacts from the Anzick Clovis Burial (Lahren 2001; Lahren and Bonnichsen 1974; Wilkie et al. 1991). However, at the time Lahren initially examined the Anzick stone tools, the Doggett Quarry seemed the only likely source for that lithic type. Since then, an extensive series of quarries in the Smith River corridor has been identified and any or all of these quarries may have provided the raw material for the Anzick assemblage. Whether continuous or sporadic in nature, the Smith River area probably has been used by prehistoric foragers from Clovis times (ca. 11,000 B.P.) through the Late Prehistoric Period.

Gallatin Valley—Logan (24GA400) and Lime Creek North

Two of the quarry sites that provided material for LA-ICP-MS analyses lie within the drainage of the Gallatin River—the easternmost of three rivers that constitute the three-forks of the Missouri River. We have identified these as the Logan Quarry (24GA400) after a small town of that name about 40 km west of Bozeman, Montana, and Lime Creek North, a small drainage in the Gallatin Canyon some 25 km southwest of Bozeman. The original selection of these quarries was to serve as proxies for larger nearby quarries that could not be accessed (e.g., Lime Creek North, the Garnet Peak Quarries) or had been made inaccessible by essentially exhausting readily available raw material (Logan Quarry, the Schmitt Site). Both locations have bedrock exposures of Madison Group (Mississippian) limestone (Wilson and Elliott 1997; Vuke et al. 2002 [revised 1/03]). Both Mission Canyon Limestone and the underlying Lodgepole Limestone exist in these exposures with chert nodules and stringers characteristic of the Lodgepole (McMannis and Chadwick 1964). The validity of the Logan-Schmitt proxy relationship requires further scrutiny. Schmitt chert probably developed in Madison Group limestone (Davis et al. 1978) but bedrock exposures in the immediate vicinity of the Logan Quarry consist exclusively of Jefferson Formation (Devonian) sediments, predominantly "light brownish-gray to medium gray, very finely crystalline to microcrystalline, sucrosic, partly pseudobrecciated dolomite" (Vuke et al. 2002 [revised 1/03]:15). Neither of these sites contains a substantial archaeological record nor can we infer when prehistoric people exploited them.

Clark Fork Valley—Avon (24PW346)

Archaeologists first recorded the Avon Quarry in 1961. Situated in the Avon Valley on the west slope of the Rocky Mountains about 50 km west of Helena, Montana, the Avon Quarry

has figured prominently in the literature of Montana archaeology (Reeves 1970), due in part to its comparatively early discovery, and the apparent distinctive characteristics of the chert. As originally identified, the Avon Quarry consisted of a number of tightly clustered quarry pits on the northeastern edge of Antelope Hill (North Avon Quarry). Subsequent work has placed the number of quarry pits at 76 (Cameron 1984) and identified additional quarry/workshop areas covering the southwest side of Antelope Hill (South Avon Quarry) and on Rhine Hill, about 1.6 km to the south. Cameron (1984:60–79) proposed consideration of a National Register District that encompassed some 28.5 km^2. The area delineated by Cameron incorporates several additional loci with quarry pits and substantial concentrations of lithic reduction debris. Many of these concentrations have received different site numbers (24PW340, 24PW1043), but lithic debris and occupational debris occur in relatively high frequency over much of the area. Most observed Avon chert artifacts have weathered to a chalky appearing, creamy, white rind. Colors of freshly exposed surfaces range from tan to dark brown with occasional pieces very dark brown and typically with a "dull to almost earthy" luster (Fields 1983). Better pieces exhibit good conchoidal fracture but this attribute varies considerably.

The geologist for the Nevada Creek Archaeological Project identified the material traditionally classed as "Avon chert" as a "mottled, white, gray, buff and yellow, highly altered mix of volcanically derived material (clay) and fossiliferous, calcareous, silicified marl or porcellanite in which fractures and pore space have been invaded by silica in the form of chalcedony" (Fields 1983:I–8, 19). Fields relates the accumulation of ash and "marl" beds in playa-like lakes to the formation of similar rocks in intermountain basins of Tertiary Age throughout western Montana (Fenneman 1931:219–223). Because the locus of deposition of the marl/porcellanite (chert) from the Avon Quarry area essentially replicates similar settings in other intermountain basins, Fields argues against the possibility of distinguishing the various silicified marls/porcellanites "either by physical appearance or possible difference in geographical source" and expresses doubt that "trace element chemistry would produce viable distinctions" (Fields 1983:1–29). Recent work has identified utilized sources of similar silicified marl/porcellanite in the vicinity of Bowman Lake on the west side of the Continental Divide in Glacier National Park (Reeves 2003:216–218). Although we failed to acquire samples from sources other than the Avon Quarry, this issue begs investigation by instrumental techniques.

Initial quarry use and/or major intervals of use remain problematic. Surface reconnaissance and excavation within the Avon area have yielded a number of lanceolate-shaped Paleo-Indian projectile points, resembling Agate Basin and later forms, but reports do not confirm Avon chert as the raw material. Two radiocarbon dates from buried soils at 24PW340 provided dates of 9620±330 BP (M-1973) and 9200±300 BP (M1974) (Davis 1982). Sadly, none of this information applies directly to the problem of quarry chronology. Archaeologists working in northwestern Montana and in the southern Canadian Rockies commonly note the presence of "Avon chert" associated with Late Middle Prehistoric Period (Post-1500 B.C.-A.D. 200) assemblages (Choquette and Holstine 1982; Loveseth 1980; Reeves 1972a; 1972b; 1974). Reeves (1970) categorizes the Avon Quarry as a component of the Besant Phase (ca. A. D. 200–700), but he also identifies "Avon Chert" as a raw material used in the production of some corner-notched dart points usually attributed to the preceding Pelican Lake Phase (1500 B. C.-A. D. 200). The Nevada Creek Archaeological Project, which included terrain surrounding the Avon Quarry, (Cameron 1984) found 12 projectile points.

They list a single Oxbow point manufactured of Avon Chert (Cameron 1984:153). Oxbow components at the Sun River Site, about 125 km to the northeast, date between about 5200 and 3500 BP (Greiser et al. 1985). This provides a crude lower limiting range for documented use of the Avon source. Additional work may yield confirmation of earlier quarry use, but for the present, the Middle Prehistoric Period represents the interval of earliest apparent use.

Clark Fork Valley—Eyebrow (24GN501).

A University of Montana Archaeological Survey crew recorded the Eyebrow Quarry in the spring of 1966 (Tro and Tro 1968). Although labeled as the Devil's Eyebrow Site" on the earliest site report forms, the USGS (U. S. Geological Survey 1989) lists the hill on the west side of the quarry area as "The Eyebrow" and locals know it by that name. The site lies to the west of Flint Creek, a northward flowing, perennial tributary of the Clark Fork River, about 17 km SSW of Drummond, Montana. The site contains an uncertain number of quarry pits ranging in size from 1–2 m in diameter and 0.50 m deep to large pits visible from a distance of nearly 2 km. The largest of the large pits probably exceeds 3 m in depth and perhaps 15–20 m in maximum horizontal extent. The size and number of quarry pits make the site stand out as an important and well-used source for lithic raw materials.

Eyebrow chert exhibits a diverse array of colors and textures. Several archaeologists have characterized Eyebrow chert on the basis of visual characteristics. Flint (1982:240) discusses the Eyebrow Quarry raw material as "...primarily of ... tan-orange-brown dendritic chert and some jasper" while Choquette identifies "...red and golden dendritic chert from sources in the Madison formation which outcrops east of Missoula" (1987:101). Either of these descriptions describes part of the variation present in samples collected from the Eyebrow Quarry in August 2002, but neither describes the entire range. Extremes range from very light, almost clear in color, to dark brown or black; black dendritic inclusions appear in most samples larger than 3 or 4 cm in diameter, but not all. The texture of newly broken pieces ranges from smooth to earthy or grainy, in part a reflection of the extent of silicification. Rare translucent pieces exist, but most range from opaque to partially translucent even on very thin margins.

The Eyebrow stands out as a prominent landmark in the Flint Creek Valley. It consists of an erosional remnant, or klippe, formed largely of faulted Cambrian Age sediments. Archaeologists have traditionally identified the Eyebrow chert as originating in Madison Limestone of Mississippian Age (Flint 1980:40). Geologic maps of the area indicate surface exposures in the immediate area consist of rocks earlier than the Madison Limestone. Lewis' (1998) 1:250,000 map identifies the Eyebrow as exposures of Ꞓs— Cambrian age sedimentary rocks with nearby PDs–Sedimentary rocks of Permian-Devonian Age, which does not preclude the possibility of Madison Limestone. A more focused 1:20,000 scale map (Maxwell 1965) that includes the Eyebrow treats the areas of the quarries as Ꞓh—Hasmark Dolomite (Cambrian) with strata of the earlier Ꞓsh—Silver Hill Formation (Cambrian) to the west and the later Ꞓrl—Red Lion Formation (Cambrian) to the east. The Devonian age Maywood Formation represents the only later Paleozoic sedimentary rock in the immediate area of the Eyebrow. The Silver Hill Formation has lateral equivalents in the Park Shale, Meagher Limestone and Wolsey Shale of central Montana (Lewis 1998). Geologically, it appears Eyebrow chert formed in Cambrian Age sedimentary rocks, probably related to the infusion of hydrothermal waters associated with Tertiary plutonism.

Very limited evidence bears on the issue of the chronology of human use of the Eyebrow Chert. Although the area surrounding the Eyebrow displays an enormous amount of chipping debris, chronologically diagnostic artifacts appear rarely and the identification of raw material used to manufacture those specimens remains mostly conjectural. Tro and Tro (1968: 20) observed that locals had known of the site "for many years" and had removed many surface artifacts. Subsequent visitors have repeated this lament (Flint 1982; Keyser et al. 1974).

Beaverhead Drainage—South Everson Creek (24BE559).

The South Everson Creek Site sprawls over several square miles of far southwestern Montana, about 66 km southwest of Dillon, Montana, and roughly 7 km north of the Continental Divide. As an upstream source for the Beaverhead River, Everson Creek contributes to the Missouri drainage and makes a relatively easy route for travel into the Northwestern Plains. The location places the site near two major passes between the Pacific and the Missouri drainages and provides a reasonable approach into the Bitterroot Valley of western Montana.

Of the quarry sites sampled for this project, the South Everson Creek Site has received the most intensive archaeological attention and the most thorough documentation. BLM records begin in 1967 with an "Archaeological Site Inventory" form completed by Claude D. Roswurm. Montana State University archaeologists conducted limited work in the early–mid 1970s and in 1979 undertook mitigation efforts prior to the installation of a cattle guard associated with a newly developed road near the site (Davis et al. 1997). In 1985, the South Everson Site attracted the attention of Robson Bonnichsen, then of the University of Maine at Orono (Bonnichsen et al. 1992). An interdisciplinary team spent parts of the years 1986–1989 conducting field investigations of South Everson and surrounding areas. Research focused on a number of issues, but quarry activity and lithic procurement received substantial attention (Bonnichsen, et al. 1992; MacWilliams 1990). A visit to South Everson rapidly convinces even the casual observer of its importance as a lithic resource. For a distance of at least several hundred meters, the bed of South Everson Creek appears to consist primarily of chipping debris and artifacts. Fresh burrows and anthills display an array of brightly colored chert chips.

MacWilliams identified seven quarry areas with a total of 196 pits spread over 800 ha (1990:38–39). Chert from South Everson displays a bewildering array of attributes. In an attempt to describe some of the variation, MacWilliams described 66 visibly different samples based on primary and secondary color using the Munsell Soil Color Charts (Kollmorgen Instruments Corporation 1975) and primary through tertiary presence of eleven additional physical attributes (petrified wood or other plant matter, gastropods, oolites, vugs, brecciated, extensively zoned or mottled, veins or welds, opaque clouds, dendrites, cortex, and poorly silicified) (MacWilliams 1990:110, 111, and Appendix 3). Hues ranged from red to yellow-red to yellow with the yellow-red hues in the 10YR series dominant (yellows, yellowish browns and browns), but he also classified specimens as white, gray, and black. Other physical attributes common in his samples included zoned or mottled, brecciated, and opaque clouds, but he also identified all other attributes (excluding veins or welds) as a primary attribute of at least one of the 66 samples.

South Everson has served as a lithic source for a very long time. Work in 1986 disclosed a mammoth bone fragment (Bonnichsen et al. 1992:294), leading to designation of the "Mammoth Meadows" locality. Subsequent work stressed excavation in the Mammoth Meadows

I locality, on terraces immediately north of South Everson Creek. Bonnichsen refers to Mammoth Meadows I as "…a stratified, multi-component workshop-habitation locus of late Pleistocene and Holocene age" (1992:306). The location has surrendered a substantial record of area prehistory, extending from Paleo-Indian times into the Late Prehistoric Period. A charcoal sample from the Cody floor (Stratum III) yielded an AMS radiocarbon date of 9,390±90 BP (TO 1976) (Bonnichsen, et al. 1992:305). The scanty cultural materials from level IV presumably date from an earlier interval.

Methods and Results

To characterize and possibly "fingerprint" chert from Montana sources, we analyzed 54 samples from the Camp Baker Quarry, two other quarries in the Smith River area (Doggett and 24ME332), and five other quarry sites throughout SW Montana by LA-ICP-MS at MURR. Additionally, four samples from Camp Baker exhibited multiple colors on the same specimen (e.g., combinations of red, brown, and/or gray). Each distinct color was analyzed independently to assess possible chemical variation in color within the same stone. This resulted in an extra 5 analyses. Collection of samples involved on-site visits to all quarries except South Everson. The BLM Billings Curation Center contributed samples from their South Everson collection. Sampling deliberately included quarries in a variety of geological contexts in an effort to evaluate regional similarities and differences. Table 2 lists descriptive information and chemical group assignments for the analyzed sample.

Laser ablation-ICP-MS requires little sample preparation other than resizing the sample to fit inside the sample chamber. For this study, samples were washed in deionized water and permitted to dry. Each sample was then crushed into coarse fragments. Relatively flat interior fragments with little or no cortex were selected for analysis.

Ablation parameters were identical for all unknowns and standards analyzed. The laser was used to ablate a line on each sample. The laser was operated using a 200-micron-wide beam, operating at 20 hz, scanning along a line at a speed of 70 microns per second. The laser was permitted to pass over the ablation area twice prior to data acquisition in order to remove contamination from the surface of the samples, to permit time for sample uptake, and to permit time for the argon gas plasma to stabilize after the introduction of the ablated material. Analytes of interest were scanned three times each and averaged. Each sample was analyzed at three discrete locations. Data generated at each of the three discrete locations was also averaged. In other words, data generated for each sample represents an average of nine measurements. Samples CBQ03, 14, and 16 contained two distinct colors/structures and sample CBQ08 contained three distinct colors/structures within the sample (see Table 2). In these cases, each distinct color/structure was also analyzed at three discrete locations.

Data were calibrated using the Gratuze method (Gratuze 1999; Gratuze et al. 2001; Neff 2003, see also Chapter 1). The analyses produced elemental concentration values for 45 elements in most of the analyzed samples. Quantitative analysis was subsequently carried out on base-10 logarithms of concentrations for these data. Use of log concentrations rather than raw data compensates for differences in magnitude between major elements, such as SiO_2, on one hand and trace elements, such as the rare earth or lanthanide elements (REEs), on the other hand. Transformation to base-10 logarithms also yields a more nearly normal distribution for many trace elements.

Figures 4–7 present the basic subgroup structure identified through analysis of the LA-ICP-MS data. Figure 4 is a variance-covariance matrix biplot derived from PCA 61 sample data set. Principal component 2 expresses enrichment of calcium, strontium, magnesium, and manganese, and dilution of silicon. Principal component 1 expresses enrichment of lanthanides and transition metals. Samples from Avon Quarry, South Everson, the gray chert from Logan Quarry, and two groups from Camp Baker—Camp Baker-1 and Camp Baker-2—are distinct in this projection of the data. The undifferentiated chert group includes samples from Camp Baker, Doggett, 24ME322, Eyebrow, and the brown chert from Logan. Although we might expect chert from Camp Baker, Doggett, and 23ME322 to share a similar chemical signature (based on their proximity to each other), it is somewhat surprising that samples from Eyebrow and Logan are similar, given their distance from Smith River Quarries and that unique signatures were discovered for the other quarries. Future research should explore the possibility of using lead and/or strontium isotope ratios in conjunction with elemental analyses to determine if it is possible to separate the Smith River undifferentiated samples from the other undifferentiated samples.

Table 2. Descriptive information and chemical group assignments for the LA-ICP-MS sample of Montana Chert.

Sample ID	Chem Group	Site Name	Site Number	Color	Context
SML028	Avon	Avon Quarry	24PW346	White	Surf
SML029	Avon	Avon Quarry	24PW346	White	Surf
SML030	Avon	Avon Quarry	24PW346	White	Surf
SML031	Avon	Avon Quarry	24PW346	White	Surf
CBQ09	Camp Baker 1	Camp Baker Quarry	24ME467	Tan	pit 21
CBQ05	Camp Baker 2	Camp Baker Quarry	24ME467	Tan	pit 21
CBQ06	Camp Baker 2	Camp Baker Quarry	24ME467	Gray	pit 21
CBQ08B	Camp Baker 2	Camp Baker Quarry	24ME467	Red	pit 21
CBQ08C	Camp Baker 2	Camp Baker Quarry	24ME467	Gray	pit 21
CBQ13	Camp Baker 2	Camp Baker Quarry	24ME467	Brown	pit 21
CBQ16A	Camp Baker 2	Camp Baker Quarry	24ME467	Brown	pit 21
CBQ01	Undifferentiated	Camp Baker Quarry	24ME467	Brown	pit 21
CBQ02	Undifferentiated	Camp Baker Quarry	24ME467	Dark brown	pit 21
CBQ03A	Undifferentiated	Camp Baker Quarry	24ME467	Gray	pit 21
CBQ03B	Undifferentiated	Camp Baker Quarry	24ME467	Dark gray	pit 21
CBQ04	Undifferentiated	Camp Baker Quarry	24ME467	Dark gray	pit 21
CBQ07	Undifferentiated	Camp Baker Quarry	24ME467	Gray	pit 21
CBQ08A	Undifferentiated	Camp Baker Quarry	24ME467	Brown	pit 21
CBQ10	Undifferentiated	Camp Baker Quarry	24ME467	Brown	pit 21
CBQ11	Undifferentiated	Camp Baker Quarry	24ME467	Tan	pit 21
CBQ12	Undifferentiated	Camp Baker Quarry	24ME467	Brown	pit 21
CBQ14A	Undifferentiated	Camp Baker Quarry	24ME467	Black	pit 21
CBQ14B	Undifferentiated	Camp Baker Quarry	24ME467	Gray	pit 21
CBQ15	Undifferentiated	Camp Baker Quarry	24ME467	Tan	pit 21
CBQ16B	Undifferentiated	Camp Baker Quarry	24ME467	Gray	pit 21
SML022	Undifferentiated	Devil's Eyebrow Quarry	24GN501	Gray	Surf
SML023	Undifferentiated	Devil's Eyebrow Quarry	24GN501	Brown	Surf
SML024	Undifferentiated	Devil's Eyebrow Quarry	24GN501	White	Surf

Table 2. Descriptive information and chemical group assignments for the LA-ICP-MS sample of Montana Chert (continued.)

SML026	Undifferentiated	Devil's Eyebrow Quarry	24GN501	Tan	Surf
SML027	Undifferentiated	Devil's Eyebrow Quarry	24GN501	White	Surf
SML001	Undifferentiated	Doggett Quarry	24ME69	Gray	Surf
SML002	Undifferentiated	Doggett Quarry	24ME69	Brown	Surf
SML003	Undifferentiated	Doggett Quarry	24ME69	Brown	Surf
SML004	Undifferentiated	Doggett Quarry	24ME69	Gray	Surf
SML005	Undifferentiated	Doggett Quarry	24ME69	Brown	Surf
SML006	Undifferentiated	Doggett Quarry	24ME69	White	Surf
SML007	Undifferentiated	Doggett Quarry	24ME69	Clear	Surf
SML016	Undifferentiated	Logan Quarry	24GA400	Brown	Surf
SML017	Undifferentiated	Logan Quarry	24GA400	Brown	Surf
SML018	Undifferentiated	Logan Quarry	24GA400	Brown	Surf
SML021	Undifferentiated	Logan Quarry	24GA400	Brown	Surf
SML008	Undifferentiated	unnamed	24ME332	Brown	Surf
SML009	Undifferentiated	unnamed	24ME332	Brown	Surf
SML010	Undifferentiated	unnamed	24ME332	Brown	Surf
SML011	Undifferentiated	unnamed	24ME332	Brown	Surf
SML012	Undifferentiated	unnamed	24ME332	Brown	Surf
SML013	Lime Creek	Lime Creek Quarry	24GA1547	Gray	Surf
SML014	Lime Creek	Lime Creek Quarry	24GA1547	Red/Gray	Surf
SML015	Lime Creek	Lime Creek Quarry	24GA1547	Brown	Surf
SML019	Logan Gray	Logan Quarry	24GA400	Gray	Surf
SML020	Logan Gray	Logan Quarry	24GA400	Gray	Surf
SML033	South Everson	South Everson Quarry	24BE559	Gray	Surf
SML034	South Everson	South Everson Quarry	24BE559	Clear	Surf
SML035	South Everson	South Everson Quarry	24BE559	White	Surf
SML036	South Everson	South Everson Quarry	24BE559	Tan	Surf
SML037	South Everson	South Everson Quarry	24BE559	Gray	Surf
SML038	South Everson	South Everson Quarry	24BE559	Brown	Surf
SML025	unassigned	Devil's Eyebrow Quarry	24GN501	Tan	Surf
SML032	unassigned	South Everson Quarry	24BE559	White	Surf

A bivariate plot of strontium and rubidium base-10 logged concentrations (Figure 5) shows separation of the Avon Quarry, Logan Gray, and Camp Baker-1 and Camp Baker-2 groups. The undifferentiated, South Everson, and Lime Creek groups overlap in this projection. However, a plot of scandium and terbium easily separate South Everson from the undifferentiated Montana chert group (Figure 6). Likewise, phosphorus discriminates the Lime Creek group from the undifferentiated group (Figure 7).

The sample that comprises Camp Baker 1 (CBQ09) is enriched in most elements and does not have a chemical signature that is consistent with chert; this leads us to suggest that this sample is a mudstone or siltstone. Chert from South Everson also has a unique chemical signature. Specifically, samples in this group are highly enriched in calcium (ca. 20%), which is not consistent with other assays of chert.

As mentioned above, several Camp Baker samples had multiple colors that were analyzed individually. In some cases (e.g., CBQ03A, 03B, 14A, and 14B), there was no difference between color and composition. However, two of these samples exhibited different chemical

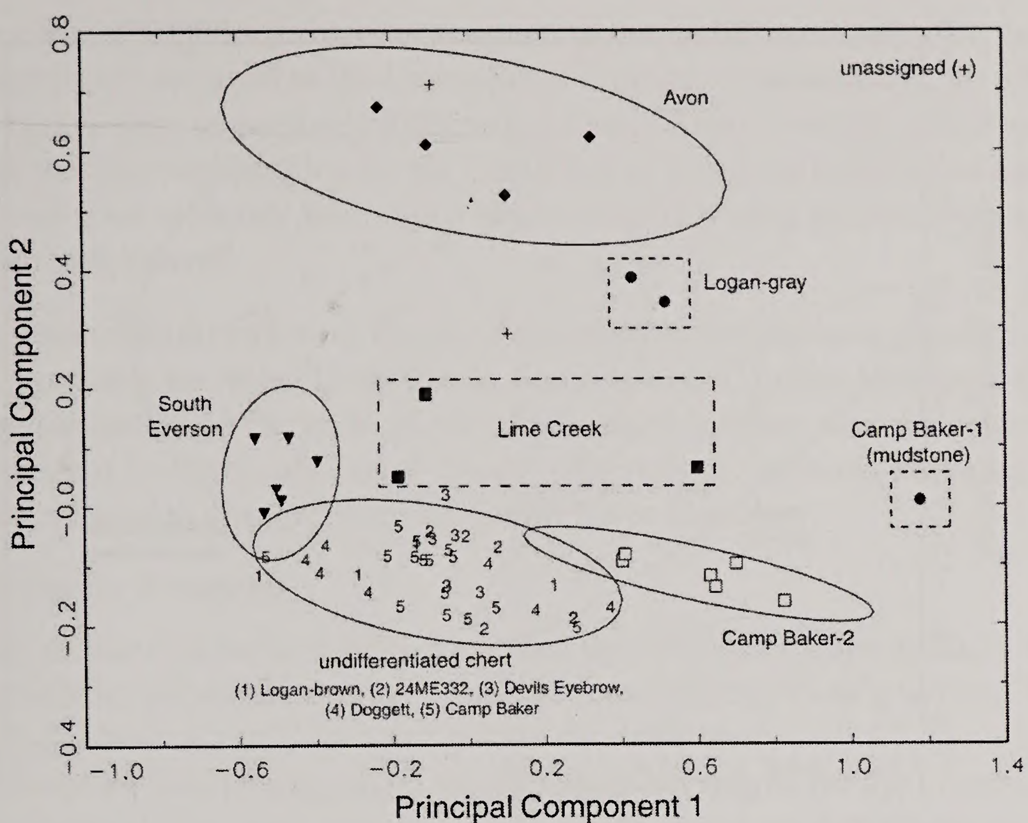

Figure 4. Variance co-variance matrix biplot of principal component 1 and 2 derived from PCA of the Montana chert LA-ICP-MS data. Ellipses represent 90% confidence interval for group membership. The provenance of samples assigned to the undifferentiated group is denoted by numbers 1–5.

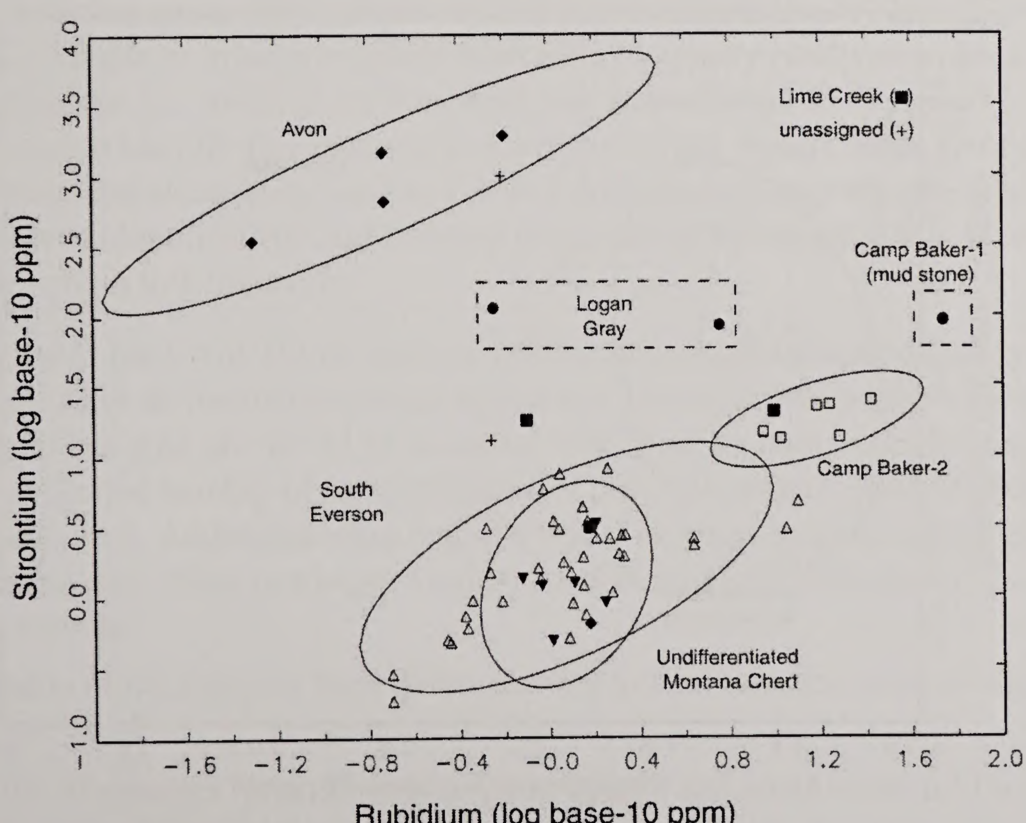

Figure 5. Bivariate plot of rubidium and strontium base-10 logged concentrations derived from LA-ICP-MS of the Montana chert sample. Ellipses represent 90% confidence interval for group membership.

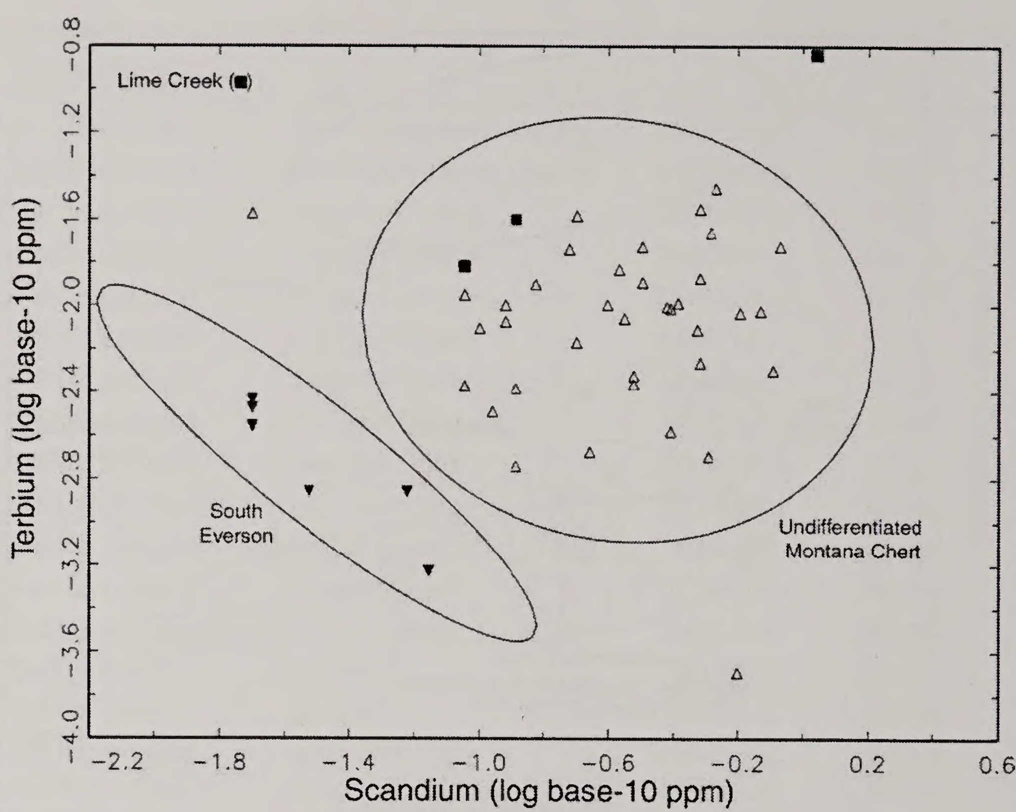

Figure 6. Bivariate plot of scandium and terbium base-10 logged concentrations for the South Everson, Lime Creek, and undifferentiated chert groups. Ellipses represent 90% confidence interval for group membership.

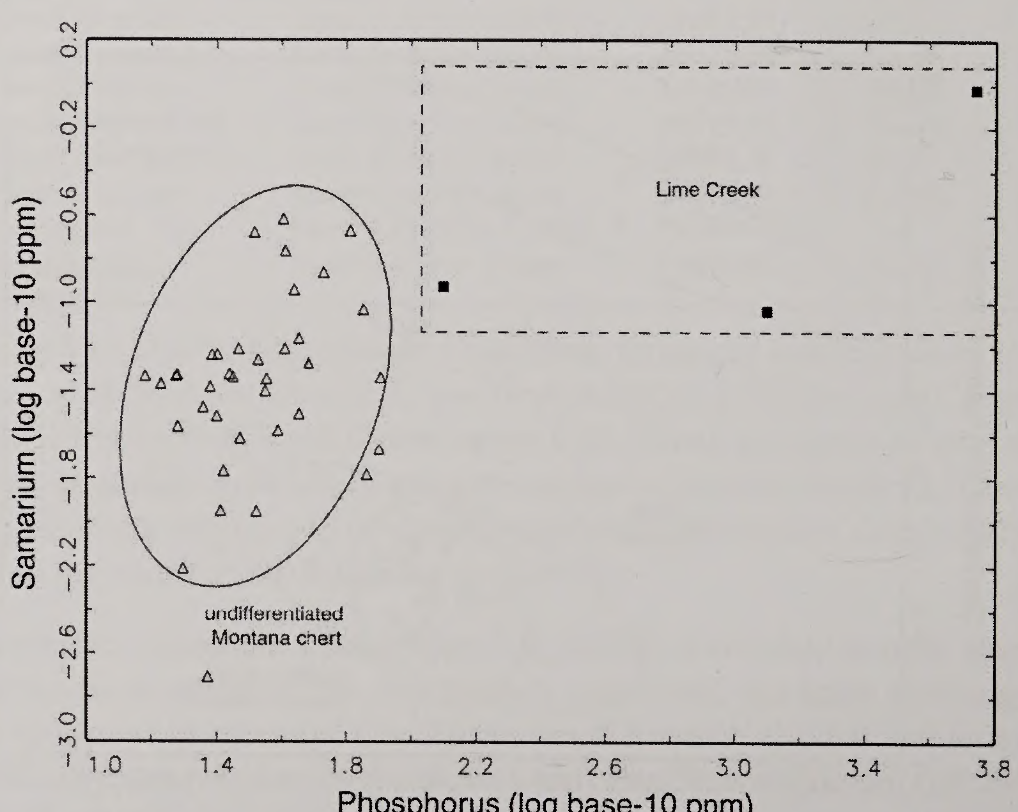

Figure 7. Bivariate plot of phosphorus and samarium base-10 logged concentrations showing differentiation of the Lime Creek samples from the undifferentiated group. Ellipses represent 90% confidence interval for group membership.

profiles. For example, CBQ08A (brown) is assigned to the undifferentiated group and CBQ08B (red) and 08C (gray) are assigned to the Camp Baker 2 group. Similarly, CBQ016A (brown) and CBQ016B (gray) were respectively assigned to Camp Baker 2 and the undifferentiated group. Although the chemical profiles for the Camp Baker 2 and the undifferentiated group are completely different, we evidently have cases where color is related to composition, although there is no discernable pattern.

Clearly, some differentiation of the chert materials in the region is possible as evidenced by the distinct signatures for Avon, Lime Creek, South Everson, Logan Gray, and Camp Baker 1 and 2. However, separation on the basis of geography alone is by no means a general rule as the geographically distant Eyebrow and Logan Quarry materials are virtually indistinguishable from the lithic materials found in quarries from the Smith River Corridor.

Summary and Future Prospects

Regional archaeologists have often identified the sources of stone artifacts based on sets of visual characteristics presumed unique to specific formations or even quarries. References to "Avon Chert", "Schmitt Chert", "red and golden dendritic chert", or "Madison formation chert", accompanied by assumptions about their source(s) of origin, fill the literature of Montana archaeology. At Camp Baker, chert samples from a single quarry pit differ dramatically in visual characteristics such as color, translucence, luster, texture, and structure. The highly variable cherts present at Camp Baker and other quarries visited provide an opportunity to test the validity of visual characterizations for the purpose of source identification. People categorize things in which they share a common interest and experience. Classification of stones based on common experience serve certain needs very adequately, but proves unsatisfactory for other purposes. Examination of a sample of lithic specimens from a single quarry rarely provides an adequate basis for attributing the raw material used in stone tool manufacture to that quarry. Visual characteristics used to identify raw material to source of origin require some form of external validation. Instrumental techniques, such as LA-ICP-MS, may or may not prove successful in the quest for "source identification", but without them, the archaeological folk taxonomies about stone types will remain folk taxonomy.

The results of the LA-ICP-MS analysis are encouraging as several of the geographically dispersed quarries have distinctive chemical signatures. However, the positive provisional nature of the results from this data set should be accepted with some caution. At this time, the small sample sizes and limited number of sampled quarries preclude reliable generalizations about regional chert resources. Additional sampling of a wider range of quarries across central and southwest Montana may result in a larger circle of undifferentiated lithic materials. Prospects for future research include:

1. • Expansion of the samples from these quarries to further refine some of the distinctive groups.

2. • Addition of samples from other quarries in central and southwestern Montana in order to create a more comprehensive regional database.

3. • Specific examination of the signatures from silicified marl/porcellanite that formed in widely separated intermontane tertiary basins of Montana west of the Continental Divide.

4. • Initiate examination of lithic materials from non-quarry archaeological contexts in order to gain an understanding of prehistoric patterns of mobility and resource use.

5. • Expand the scope of the analysis to include other lithic types such as the baked shale/ porcellanite" and non-volcanic natural glass common to the unglaciated plains of eastern Montana and northeastern Wyoming.

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Gallatin Forest archaeologist Walt Allen made his intern, Tom Ballard available to guide us to the newly discovered Lime Creek North Quarry at a time when forest fires converted all forest personnel into emergency fire fighters and made most parts of the forest inaccessible.

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Dr. David Lageson, geologist with the Department of Earth Sciences at Montana State University tried to lead one of us (TER) through the train wreck that comprises the tectonics of western Montana. Lageson's comprehensive knowledge of that topic should not be faulted for any inadequacies in our discussion of Montana geology.

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Appendix D

XRF Analysis of Obsidian

By

Richard E. Hughes
Geochemical Research Laboratory

Geochemical Research Laboratory Letter Report 2001-51

June 12, 2001

Dr. Tom E. Roll
Professor Emeritus
Department of Sociology & Anthropology
Montana State University
Bozeman, Montana 59717-2380

Dear Tom:

On page two of this letter you will find a table presenting energy dispersive x-ray fluorescence (edxrf) data generated from the analysis of two obsidian artifacts; one each from archaeological sites 24ME75 and 24ME467 in southwestern Montana. The xrf research reported herein was completed pursuant to your letter request of June 7, 2001.

Analyses of obsidian are performed at my laboratory on a Spectrace™ 5000 (Tracor X-ray) energy dispersive x-ray fluorescence spectrometer equipped with a rhodium (Rh) x-ray tube, a 50 kV x-ray generator, with microprocessor controlled pulse processor (amplifier) and bias/protection module, a 100 mHz analog to digital converter (ADC) with automated energy calibration, and a Si(Li) solid state detector with 160 eV resolution (FWHM) at 5.9 keV in a 30 mm^2 area. The x-ray tube is operated at 34.0 kV, .26 mA, using a .127 mm Rh primary beam filter in an air path to generate x-ray intensity data for elements zinc (Zn $K\alpha$), gallium (Ga $K\alpha$), rubidium (Rb $K\alpha$), strontium (Sr $K\alpha$), yttrium (Y $K\alpha$), zirconium (Zr $K\alpha$), and niobium (Nb $K\alpha$). Barium (Ba $K\alpha$) intensities are generated by operating the x-ray tube at 50.0 kV, .35 mA, with a .63 mm copper (Cu) filter, while those for titanium (Ti $K\alpha$), manganese (Mn $K\alpha$) and total iron ($Fe_2O_3^T$) are generated by operating the x-ray tube at 15.0 kV, .30 mA with a .127 mm aluminum (Al) filter. Iron vs. manganese (Fe $K\alpha$/Mn $K\alpha$) ratios are computed from data generated by operating the x-ray tube at 15.0 kV, .30 mA, with a .127 mm aluminum (Al) filter. Deadtime-corrected analysis time for each sample appears in the data table.

X-ray spectra are acquired and elemental intensities extracted for each peak region of interest, then matrix correction algorithms are applied to specific regions of the x-ray energy spectrum to compensate for inter-element absorption and enhancement effects. After these corrections are made, intensities are converted to concentration estimates by employing a least-squares calibration line established for each element from analysis of up to 30 international rock standards certified by the U.S. Geological Survey, the U.S. National Institute of Standards and Technology, the Geological Survey of Japan, the Centre de Recherches Petrographiques et Geochimiques (France), and the South African Bureau of Standards. Further details pertaining to x-ray tube operating conditions and calibration appear in Hughes (1988, 1994b). Extremely small/thin specimens are analyzed using a .25 mm^2 primary beam collimator, and resulting data normalized using a sample mass correction algorithm. Deadtime-corrected analysis time is greatly extended in all instances when primary beam collimation is employed.

Trace element measurements on the xrf data table are expressed in quantitative units (i.e. parts per million [ppm] by weight), and matches between unknowns and known obsidian chemical groups are made on the basis of correspondences (at the 2-sigma level) in diagnostic trace element concentration values (in this case, ppm values for Rb, Sr, Y, Zr, Nb, Ba, Ti, Mn and $Fe_2O_3^T$) that appear in Anderson et al. (1986), Baugh and Nelson (1987, 1988), Glascock et al. (1999), Hughes (1984), Hughes and Nelson (1987), Jack (1971), Nelson (1984), Shackley (1995, 1998), and unpublished data on other Utah and Wyoming obsidians (Hughes 1994a; 1995a, b; 1997). Artifact-to-obsidian source (geochemical type, *sensu* Hughes 1998) correspondences were considered reliable if diagnostic mean measurements for artifacts fell within 2 standard deviations of mean values for source standards. I use the term "diagnostic" to specify those trace elements that are well-measured by x-ray fluorescence, and whose concentrations show low intra-source variability and marked variability across sources. In short, diagnostic

elements are those concentration values allowing one to draw the clearest geochemical distinctions between sources (Hughes 1990, 1993). Although Zn, Ga and Nb ppm concentrations also were measured and reported for each specimen, they are not considered "diagnostic" because they don't usually vary significantly across obsidian sources (see Hughes 1982, 1984). This is particularly true of Ga, which occurs in concentrations between 10-30 ppm in nearly all parent obsidians in the study area. Zn ppm values are infrequently diagnostic; they are always high in Zr-rich, Sr-poor peralkaline volcanic glasses, but otherwise they do not vary significantly between sources in the study area vicinity.

The trace element composition measurements in the enclosed table are reported to the nearest ppm to reflect the resolution capabilities of non-destructive energy dispersive x-ray fluorescence spectrometry. The resolution limits of the present x-ray fluorescence instrument for the determination of Zn is about 3 ppm; Ga about 2 ppm; for Rb about 4 ppm; for Sr about 3 ppm; Y about 2 ppm; Zr about 4 ppm; Nb about 2 ppm; and Ba about 10 ppm (see Hughes [1994b] for other elements). When counting and fitting error uncertainty estimates (the "±" value in the table) for a sample are greater than calibration-imposed limits of resolution, the larger number is a more conservative indicator of composition variation and measurement error arising from differences in sample size, surface and x-ray reflection geometry.

	Trace Element Concentrations											Ratio	
Cat. Number	Zn	Ga	Rb	Sr	Y	Zr	Nb	Ba	Ti	Mn	$Fe_2O_3^T$	Fe/Mn	Obsidian Source (Chemical Type)
24ME75,	75	19	234	5	72	156	38	nm	524	227	1.32	nm	Obsidian Cliff, WY
IF #2	±5	±3	±4	±3	±3	±4	±3		±16	±11	±.10		
24ME467,	73	22	236	5	75	161	39	nm	602	241	1.32	nm	Obsidian Cliff, WY
P21, U113	±6	±3	±4	±3	±3	±4	±3		±17	±11	±.10		

Values in parts per million (ppm) except total iron [in weight %] and Fe/Mn intensity ratios; ± = expression of x-ray counting uncertainty and regression fitting error at 300 seconds livetime. nm= not measured.

Xrf data indicate that both artifacts have the same trace element composition as volcanic glass of the Obsidian Cliff geochemical type, Wyoming (cf. Anderson et al. 1986: Table 4; Hughes 1995a: Table 2).

I hope this information will help in your analysis and interpretation of other materials from these sites. Please contact me at my laboratory ([650] 851-1410; e-mail: rehughes@silcon.com) if I can be of further assistance.

Sincerely,

Richard E. Hughes, Ph.D.
Director, Geochemical Research Laboratory

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Appendix E

Summary data for debitage categories by provenience and size class for Camp Baker Quarry, Pit 4 all units, Pit 21, Unit 112.

Table 1. Camp Baker Quarry, Pit 4 all units, Pit 21, Unit 112, debitage categories CC1 through WN7 by provenience and size class (see Fig 21, p24 and Table 6, p28).

Pit	Unit	Level	SizeClass	CC1	CC2	CN1	CN2	WC1	WC2	WC3	WC4	WC5	WC6	WC7	WC8	WC9	WC10	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	WN1	WN2	WN3	WN4	WN5	WN6	WN7
4	18	VI	2																									1						
4	18	VI	4																															
4	18	VII	2																										1				1	
4	18	VII	3																										3					1
4	18	VII	4																															
4	18	VII	5																															
4	18	VIII	2																										1					
4	18	VIII	3																															
4	18	VIII	4										1																				1	
4	18	VIII	5																															
4	18	VIII	6																															
4	18	VIII	7																										1					
4	18	VIII	9																										1					
4	18	IX	2																										1					
4	18	IX	3																														1	
4	18	IX	4							1																								
4	18	IX	5																										1					
4	18	IX	9																															
4	18	X	1																															
4	18	X	2																										2				1	
4	18	X	3																										1				1	
4	18	X	4																										1				2	
4	18	X	5				1																											1
4	18	X	6																															
4	18	X	10	1																														
4	19	I	2																															
4	19	I	3																															
4	19	I	5																															
4	19	II	1																															
4	19	II	2																										3	1			2	
4	19	II	2																										3		1		3	1
4	19	II	3						1																				4				2	1
4	19	II	4						1																			1	2				3	1
4	19	II	5					1					1																3					1
4	19	II	6																										1					
4	19	II	7																										2					
4	19	II	8	1																														
4	19	III	3																1										9		1		2	2

Table 1. Camp Baker Quarry, Pit 4 all units, Pit 21, Unit 112, debitage categories CC1 through WN7 by provenience and size class (see Fig 21, p24 and Table 6, p28) (continued).

Pit	Unit	Level	SizeClass	CC1	CC2	CN1	CN2	WC1	WC2	WC3	WC4	WC5	WC6	WC7	WC8	WC9	WC10	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	WN1	WN2	WN3	WN4	WN5	WN6	WN7
4	19	III	4						1																				5	1	1		2	2
4	19	III	5						1	1	1																		8					1
4	19	III	6																										4					
4	19	III	7																										3		1			
4	19	III	8		1																								1					
4	19	III	9	1																														
4	19	IV	2																										2		1			
4	19	IV	3																										16	2	3	1	1	
4	19	IV	4						1									1											8	3	3		4	3
4	19	IV	5					1																					3				1	
4	19	IV	6																										3	2	2			1
4	19	IV	7					1	2		1																	1	2					
4	19	IV	8																									1						
4	19	IV	9																															
4	19	IV	10																															
4	19	IV	99	1																														
4	19	V	1																															
4	19	V	2																1										3					
4	19	V	3																										1					
4	19	V	4																															
4	19	V	5																															
4	19	V	6						1																									
4	19	V	7						1																									
4	19	V	8																															
4	19	V	9																															
4	19	V	14																															
4	19	V	99																										1					
4	19	VI	3						1																				1					
4	19	VI	5																															
4	19	VI	6																															
4	19	VI	8																															
4	20	I	2																															
4	20	I	3																											1				
4	20	I	4																															
4	20	I	5																										1					
4	20	I	6																															
4	20	I	7																															
4	20	I	8																															
4	20	I	9			1																												

Table 1. Camp Baker Quarry, Pit 4 all units, Pit 21, Unit 112, debitage categories CC1 through WN7 by provenience and size class (see Fig 21, p24 and Table 6, p28) (continued).

Pit	Unit	Level	SizeClass	CC1	CC2	CN1	CN2	WC1	WC2	WC3	WC4	WC5	WC6	WC7	WC8	WC9	WC10	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	WN1	WN2	WN3	WN4	WN5	WN6	WN7
4	20	II	2																															
4	20	II	3																1															
4	20	II	4																															
4	20	II	5																															
4	20	II	6																										1					
4	20	II	7						1																									
4	20	II	8																															
4	20	III	1																										3				2	
4	20	III	2						2				1	1															31		1		13	3
4	20	III	3					1						1					1										16	3	2		13	2
4	20	III	4						3				2			1													10				6	1
4	20	III	5																										1					
4	20	III	5																1									1	1				1	
4	20	III	6						2	1				1															2				1	1
4	20	III	7						1				1																1				1	
4	20	III	8	1					1																				2				1	
4	20	III	9	1					1																				2					
4	20	III	10																															
4	20	IV	2								1																		2					
4	20	IV	9	1																														
4	20	IV	10																															
4	20	IV	11			2																												
4	20	IV	12				1																											
4	21	IV	1																															
4	21	IV	2																															
4	21	IV	3					1																										
4	21	IV	4																										2					
4	21	IV	5																										3	1	2			
4	21	IV	6				1																						3	1				
4	21	IV	7																										2					
4	21	IV	8																										1					
4	21	IV	9						1																				1				1	
4	21	IV	10																															
4	21	IV	99																															
21	112	I	2																										3				1	
21	112	I	3					2																					5					
21	112	I	4					1																					5					
21	112	I	5					1																					1					
21	112	I	6																1										4					

Table 1. Camp Baker Quarry, Pit 4 all units, Pit 21, Unit 112, debitage categories CC1 through WN7 by provenience and size class (see Fig 21, p24 and Table 6, p28) (continued).

Pit	Unit	Level	SizeClass	CC1	CC2	CN1	CN2	WC1	WC2	WC3	WC4	WC5	WC6	WC7	WC8	WC9	WC10	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	WN1	WN2	WN3	WN4	WN5	WN6	WN7
21	112	I	7						1																				1					
21	112	I	8			1			1																									
21	112	I	9																										1					
21	112	I	10																										1					
21	112	I	13																															
21	112	II	2																										3			1	1	
21	112	II	3					2		1			1															1	17	1	2	2	6	
21	112	II	4					1																				1	9	2	5	1	3	
21	112	II	5	1		1							2															2	8	1	3	1		
21	112	II	6			1		1	1		2	1						1												3	1			
21	112	II	7					1	2		1																			1				
21	112	II	8					2																					2					
21	112	II	9							2																			1					
21	112	II	10																															
21	112	III	2																										6					
21	112	III	3																										11	1	2	1	4	
21	112	III	4										1										1						10	1	2	1	1	
21	112	III	5																									2	1	2		1		
21	112	III	6															1	1										1	1			1	
21	112	III	7							1																					1			
21	112	III	8						1																									
21	112	III	10																															
21	112	III	11	1																														
21	112	III	15																															
21	112	III	99																															
21	112	IV	1																															
21	112	IV	2																										1		1			
21	112	IV	3					1	1				1															3	8	2	4	4		
21	112	IV	4					2															1					1	5	1	1		1	
21	112	IV	5									1																1	8		5	1	1	
21	112	IV	6						4																				8		2			
21	112	IV	7	1				1																					4		1		1	
21	112	IV	8																										4					
21	112	IV	9			1																							1					
21	112	IV	10										1																					
21	112	IV	11																										1					
21	112	IV	15	1																														
21	112	IV	99																															
21	112	V	1																															

Table 1. Camp Baker Quarry, Pit 4 all units, Pit 21, Unit 112, debitage categories CC1 through WN7 by provenience and size class (see Fig 21, p24 and Table 6, p28) (continued).

Pit	Unit	Level	SizeClass	CC1	CC2	CN1	CN2	WC1	WC2	WC3	WC4	WC5	WC6	WC7	WC8	WC9	WC10	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	WN1	WN2	WN3	WN4	WN5	WN6	WN7
21	112	V	2																									10	13	3	3	2	1	
21	112	V	3																									30	11	3	9	3	3	
21	112	V	4			1																						4	17	1	1		4	
21	112	V	5						1		1																		4				2	
21	112	V	6								1																		3	1				
21	112	V	7																										4	1	1			
21	112	V	8			1																							2	1				
21	112	V	9																															
21	112	V	10	1																										1				
21	112	V	11																															
21	112	VI	1																										2	1				
21	112	VI	2																									1	22			1	4	
21	112	VI	3					3																					14			1	4	
21	112	VI	4					2			1																	2	10		3		1	
21	112	VI	5					2	1				1																11				1	
21	112	VI	6	1					1	1			1															1	2					
21	112	VI	7	1					3																				5				1	
21	112	VI	8					1	1																									
21	112	VI	9						1																									
21	112	VI	10																															
21	112	VI	11	1																														
21	112	VI	12			2																												
21	112	VI	15																															
21	112	VII	1																									1	16		1		4	
21	112	VII	2					1	1										1									10	117	1	6	4	33	3
21	112	VII	3			1		10	11	1			1													1		13	109	8	9		33	1
21	112	VII	4					1	10				2															4	49	2		1	6	1
21	112	VII	4						1																			1	20	1	4	2	1	
21	112	VII	5	1				1	2										2									1	18	1	1		2	
21	112	VII	5						4		2							2	1										3		2			
21	112	VII	5	1	2				4				2						1										16	1				1
21	112	VII	5			2			1																					1			1	
21	112	VII	6	2			1	1	11				1							1									20	1			2	
21	112	VII	6			1		2	3																				5		1		2	
21	112	VII	7	1				4	4																				14					3
21	112	VII	7					1	3				1																4	1				
21	112	VII	8		1				1																				1	1	2			
21	112	VII	8	1				1				2								1									2				1	
21	112	VII	8						2																							10		

Table 1. Camp Baker Quarry, Pit 4 all units, Pit 21, Unit 112, debitage categories CC1 through WN7 by provenience and size class (see Fig 21, p24 and Table 6, p28) (continued).

Pit	Unit	Level	SizeClass	CC1	CC2	CN1	CN2	WC1	WC2	WC3	WC4	WC5	WC6	WC7	WC8	WC9	WC10	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	WN1	WN2	WN3	WN4	WN5	WN6	WN7
21	112	VII	9		1			1	3				1																1					
21	112	VII	9										1																1					
21	112	VII	10					1						1															2					
21	112	VII	11																															
21	112	VII	12																															
21	112	VII	13																															
21	112	VIII	1																										5		11			
21	112	VIII	2						3																			9	52	4	8	1	23	8
21	112	VIII	3					8	1	1	1																	5	41	4	9		12	3
21	112	VIII	4					2	5	1	1					1												2	27	1	3		14	2
21	112	VIII	5		1	1		1	3			1	1					1	1								1	2	8		1		3	1
21	112	VIII	6						3					1				1										2	4					
21	112	VIII	7																										5				1	1
21	112	VIII	8	1		2		1																					1					
21	112	VIII	9																															
21	112	VIII	10		1																													
21	112	VIII	12			1																												
21	112	IX	1																									2	2					
21	112	IX	2					3	2				1										1					6	31		1		11	4
21	112	IX	3					4	4				1															4	17		1		8	1
21	112	IX	4								1		1															1	13			1	3	
21	112	IX	5		1			1																				1	1				2	
21	112	IX	6					1																				2	2					
21	112	IX	7																															
21	112	IX	8																															
21	112	IX	9			1																												
21	112	IX	10																													1		
21	112	IX	12																															
21	112	IX	14																										1					
21	112	XX	99																															

Table 2. Camp Baker Quarry, Pit 4 all units, Pit 21, Unit 112, debitage categories WN8 through DN3 and notes by provenience and size class (see Fig 21, p24 and Table 6, p28).

Pit	Unit	Level	SizeClass	WN8	WN9	WN10	PN1	PN2	PN3	PN4	PN5	PN6	PN7	PN8	PN9	PN10	DC1	DC2	DC3	DN1	DN2	DN3	Notes
4	18	VI	2																				
4	18	VI	4																2				
4	18	VII	2																	2		1	
4	18	VII	3					1				1							1	1		2	
4	18	VII	4																			1	
4	18	VII	5															1					
4	18	VIII	2										1									1	
4	18	VIII	3																	1	3		
4	18	VIII	4																1		1	1	
4	18	VIII	5																			2	
4	18	VIII	6																		1		
4	18	VIII	7																				
4	18	VIII	9																				
4	18	IX	2					1												2			
4	18	IX	3																	2	2	2	
4	18	IX	4																			1	
4	18	IX	5																		1		
4	18	IX	9																	1			
4	18	X	1									1											
4	18	X	2																	1		1	
4	18	X	3															1		1	1		
4	18	X	4																		1	1	
4	18	X	5																		1		1-WN7 exhibits platform crushing
4	18	X	6															1				2	1-DN3,unfiacial flaking on 3 margins, abandoned attempt at scraper tool?
4	18	X	10																				
4	19	I	2																	1		1	
4	19	I	3																		5	2	
4	19	I	5																		1		
4	19	II	1																	1			
4	19	II	2					1											3	13		18	
4	19	II	2					1				1			1					8		10	more patina on all surfaces of flakes than other levels/units
4	19	II	3		1									1						7		6	
4	19	II	4	1															2	7	1	2	
4	19	II	5															1				3	
4	19	II	6														1						
4	19	II	7																			1	'-DN3 has possible unifacially worked edge
4	19	II	8																				
4	19	III	3					2									2		4	21	8	15	

Table 2. Camp Baker Quarry, Pit 4 all units, Pit 21, Unit 112, debitage categories WN8 through DN3 and notes by provenience and size class (see Fig 21, p24 and Table 6, p28) (continued).

Pit	Unit	Level	SizeClass	WN8	WN9	WN10	PN1	PN2	PN3	PN4	PN5	PN6	PN7	PN8	PN9	PN10	DC1	DC2	DC3	DN1	DN2	DN3	Notes
4	19	III	4														2	1		9	12	2	1-WN7 split and faceted platform
4	19	III	5					1										2	1	1	3	3	
4	19	III	6					1			1						2	3		3	2	2	1-PN5 cone platform
4	19	III	7														1				5		
4	19	III	8																				1 discard
4	19	III	9																				1-alternating platform tabular CC1
4	19	IV	2	1	3															10	1	3	
4	19	IV	3		11		1	4	1								2	1		9	14	30	
4	19	IV	4	1				3									1	7	1	9	18	11	
4	19	IV	5		1	1		1										2		3	23	3	
4	19	IV	6		1													1		1	12	3	
4	19	IV	7															2		2	9		
4	19	IV	8															2		2	7		
4	19	IV	9															1					
4	19	IV	10																				1 core rejuvenation piece
4	19	IV	99																				
4	19	V	1							1										1		2	
4	19	V	2												1								
4	19	V	3															1		2		3	
4	19	V	4																			1	
4	19	V	5																		1		
4	19	V	6					1													1		
4	19	V	7																				
4	19	V	8															1					
4	19	V	9															1					
4	19	V	14																	1			fragment of a large flake refits with P4 V19 LV class 99 WN2
4	19	V	99																				refits with P4 V19 LV class 14 DN1
4	19	VI	3																			1	
4	19	VI	5														1						
4	19	VI	6					1															
4	19	VI	8																		1		
4	20	I	2																		1	3	
4	20	I	3																		2	3	
4	20	I	4															2			1		
4	20	I	5					1													2	2	
4	20	I	6					1														1	
4	20	I	7																			1	
4	20	I	8																		1		
4	20	I	9																				

Table 2. Camp Baker Quarry, Pit 4 all units, Pit 21, Unit 112, debitage categories WN8 through DN3 and notes by provenience and size class (see Fig 21, p24 and Table 6, p28) (continued).

Pit	Unit	Level	SizeClass	WN8	WN9	WN10	PN1	PN2	PN3	PN4	PN5	PN6	PN7	PN8	PN9	PN10	DC1	DC2	DC3	DN1	DN2	DN3	Notes
4	20	II	2																			3	
4	20	II	3																		1	2	
4	20	II	4																1	1		1	
4	20	II	5																		3		
4	20	II	6																		1	1	
4	20	II	7																		1		
4	20	II	8															1				1	
4	20	III	1																	8	1	8	
4	20	III	2		2			7				3						8	4	36	17	76	
4	20	III	3		2			2				4					5	8	7	23	5	25	
4	20	III	4		1			5										7	7	16	13	17	
4	20	III	5					1					1					2	2	3	2	4	
4	20	III	5					3				1							2	5	4	7	1-PN6 has 2 bulbs/impacts
4	20	III	6															5	5	4	3	5	
4	20	III	7														2	3		1	2	3	
4	20	III	8															3		1		1	
4	20	III	9															2	1		3		
4	20	III	10																	1			
4	20	IV	2		3																	23	
4	20	IV	9															1			2		
4	20	IV	10																		1		
4	20	IV	11																				
4	20	IV	12																				
4	21	IV	1																	3			
4	21	IV	2		4			1		1		1					1			10		13	
4	21	IV	3																1	15	6	6	
4	21	IV	4		1							1						1		4	9	7	
4	21	IV	5			1														3	10	3	
4	21	IV	6																	1	5	2	
4	21	IV	7							1											3		
4	21	IV	8																				
4	21	IV	9																		1		
4	21	IV	10																		1		
4	21	IV	99																				1 green argillite cobble fragment
21	112	I	2					1			1									3		2	1 spall, 1 split pebble frag.
21	112	I	3					1															
21	112	I	4		3										1		1			11	1	4	
21	112	I	5		2			1										2	4	2	1	6	
21	112	I	6		1												1	3	1	3	1		

Table 2. Camp Baker Quarry, Pit 4 all units, Pit 21, Unit 112, debitage categories WN8 through DN3 and notes by provenience and size class (see Fig 21, p24 and Table 6, p28) (continued).

Pit	Unit	Level	SizeClass	WN8	WN9	WN10	PN1	PN2	PN3	PN4	PN5	PN6	PN7	PN8	PN9	PN10	DC1	DC2	DC3	DN1	DN2	DN3	Notes
21	112	I	7															2		2	1		
21	112	I	8															1					
21	112	I	9																				1 chunk conglomerate
21	112	I	10																				
21	112	I	13																		1		
21	112	II	2									1					1			7	2	3	
21	112	II	3		4			1				3		1			2	2	2	14	5	11	
21	112	II	4		2		1						1		2		2	2		20	11	7	
21	112	II	5					2				1					3	3		11	10	1	
21	112	II	6					1									2	2		6	6	2	
21	112	II	7															2			2	1	
21	112	II	8																	1	6	1	
21	112	II	9															1					
21	112	II	10															1					
21	112	III	2		1															4		3	
21	112	III	3		3												2	2		16	8	3	
21	112	III	4						1								2			10	9	3	
21	112	III	5		4		1	2										1		7	3		
21	112	III	6					1										1		2	8		
21	112	III	7																	1	3		
21	112	III	8																	1			
21	112	III	10																		1		
21	112	III	11																				
21	112	III	15																				1 tested nodule frag.
21	112	III	99																				1 core on a flake <10% cortex.
21	112	IV	1																2			2	
21	112	IV	2		1					2		2						1		5	3	10	
21	112	IV	3		3			6				1	1				2	3		16	11	11	
21	112	IV	4		3			3				1	1				1			10	25	10	
21	112	IV	5					1										4	2	4	1	5	
21	112	IV	6										1				3	4		1	14	4	
21	112	IV	7		1													4		1	7		
21	112	IV	8																		2		1 possible tool, spokeshave/beak?
21	112	IV	9																		2		
21	112	IV	10															1			2		
21	112	IV	11																				
21	112	IV	15																				
21	112	IV	99															1					
21	112	V	1																			2	

Table 2. Camp Baker Quarry, Pit 4 all units, Pit 21, Unit 112, debitage categories WN8 through DN3 and notes by provenience and size class (see Fig 21, p24 and Table 6, p28) (continued).

Pit	Unit	Level	SizeClass	WN8	WN9	WN10	PN1	PN2	PN3	PN4	PN5	PN6	PN7	PN8	PN9	PN10	DC1	DC2	DC3	DN1	DN2	DN3	Notes
21	112	V	2		9			2			1									8	1	19	2 spalls
21	112	V	3					1									1	1	1	30			
21	112	V	4		4			1					1					1		3	27	9	1 ground platform, 1 biface,
21	112	V	5		2			1	1								2	1		4	18	6	
21	112	V	6		1				1						1			4	2	1	12	1	one piece, the darkest brown, has aprox 4 cm of bifacial, roughly flaked
21	112	V	7															4			5	1	
21	112	V	8															3	1		7		
21	112	V	9															1	1		2		
21	112	V	10																		1		
21	112	V	11																				
21	112	VI	1		1												1	1		8	3		
21	112	VI	2		3			4				2					4			36	5	49	
21	112	VI	3		3			1		1			1				6	3	16	38	19	52	
21	112	VI	4		1			3									4	9		16	17	34	spurred scraper?
21	112	VI	5		1	2							2			1	1	2	4	5	12	26	
21	112	VI	6					1										4	5	1	7	6	
21	112	VI	7														1	4	7		5	10	
21	112	VI	8														1	1	3	1	4	7	
21	112	VI	9																1		3	1	
21	112	VI	10																		3		
21	112	VI	11															1			2		
21	112	VI	12																				
21	112	VI	15																				
21	112	VII	1	1	1		1										6	1	9	53		15	
21	112	VII	2		7	5	1	8				3			1		19	9	41	236	16	194	
21	112	VII	3	3	31	6		20				2			1		19	9	69	215	28	207	
21	112	VII	4					5				1					13	9	47	57	3	93	
21	112	VII	4	2	4	3	1	2	1		1												1-ppn1 blade, 2-WN2 bladelets, 1-WN5 bladelet, 1-WN9 bladelet, 1-PN5
21	112	VII	5					1				1					6	7	12	10	6	15	
21	112	VII	5		2		1	3	1							1	3	7		9	9	5	1-PN3 blade, 1-WN2 bladlet
21	112	VII	5					4									2	3	6	7	6	8	1-DN1 shows mild bifacial flaking
21	112	VII	5			1												1	11	4	4	9	1-wn2 with two bulbs of percussion
21	112	VII	6			1		4									1	10	20	9	3	32	
21	112	VII	6		1			1									1	6	4	1	6	5	1-CC1 shows bifacial flaking
21	112	VII	7														4	10	8	3	5	12	
21	112	VII	7		1												2	5		5	11		1-WC2 blade, 1-WN2, 1-WN9 blade
21	112	VII	8					1										4		1	2		
21	112	VII	8												1			1		2	4		1 possible spokeshave
21	112	VII	8																3			3	1-DN3 extensive crushing/flaking of approx. 6 cm one concave edge, little

Table 2. Camp Baker Quarry, Pit 4 all units, Pit 21, Unit 112, debitage categories WN8 through DN3 and notes by provenience and size class (see Fig 21, p24 and Table 6, p28) (continued).

Pit	Unit	Level	SizeClass	WN8	WN9	WN10	PN1	PN2	PN3	PN4	PN5	PN6	PN7	PN8	PN9	PN10	DC1	DC2	DC3	DN1	DN2	DN3	Notes
21	112	VII	9	1													3	2	5	1		1	
21	112	VII	9														2	1	1				1-WC6 shows two side-by-side bulbs of percussion
21	112	VII	10															5	2			3	
21	112	VII	11															1					
21	112	VII	12														1	1			1		
21	112	VII	13																		1		
21	112	VIII	1			1											3	2	5	38	9	17	
21	112	VIII	2	1	9			14	1	3	2	9			2	1	21	10	18	202	49	136	1- WN3 bladelet
21	112	VIII	3	2	3		1	11		1							20	18	20	106	56	75	2-WN2 bladelets
21	112	VIII	4		1			5				2					9	13	12	47	27	36	1-WN7 mild grinding, 1-WC2 blade, 1-WN6 blade, 1-WN2 blade
21	112	VIII	5					2				1					4	20	7	7	25	6	
21	112	VIII	6					1									2	6	7	3	6	12	1-WN2 interesting bipolar flake with overshot back towards original
21	112	VIII	7																5		3	4	
21	112	VIII	8					1										7					
21	112	VIII	9																		4		
21	112	VIII	10															3					2- DC2 show flaking, one shows one ? Flake scare, 1 w/ numerous
21	112	VIII	12																				
21	112	IX	1									1							5	18	8	18	
21	112	IX	2				1	5				2					11	30	34	82	28	121	
21	112	IX	3		5		1	2		1		1					4	12	11	36	30	44	1 erraillure flake
21	112	IX	4		1	1						1					4	11	10	18	8	9	
21	112	IX	5														2	2	5	3	5	7	
21	112	IX	6					2										2		1	3	1	
21	112	IX	7															2			2	1	
21	112	IX	8																		1		
21	112	IX	9																				
21	112	IX	10																				platform partially crushed
21	112	IX	12																1				
21	112	IX	14																				
21	112	XX	99																				

THE CAMP BAKER QUARRY (24ME467): 2001

In 2001, Montana State University archeologists conducted fieldwork at the Camp Baker Quarry (24ME467) through an Assistance Agreement with the Bureau of Land Management Montana State Office. Initially work consisted of detailed surface mapping in the vicinity of the quarry pits and test excavations of two of the pits. In 2002 a pedestrian reconnaissance survey was conducted on surrounding BLM lands. Once field work was completed the materials collected from the site were analyzed. Recovered cultural materials included a limited number of formal artifacts and approximately 14,000 pieces of debitage.

Chemical characterization of Camp Baker chert and seven other chert sources has provided direction for future work. Some chert sources, e.g., three quarries in the Smith River area, one quarry in the Gallatin Valley and one quarry in the Flint Creek Valley, were indistinguishable from each other. However, the Avon Quarry in the Avon Valley, the South Everson Quarry in the Beaverhead Valley, and the Lime Creek North Quarry in the upper Gallatin Valley yielded chemical signatures different from each other and from other quarries sampled by the study.

Tom E. Roll is Professor Emeritus of Anthropology from Montana State University. After receiving his Ph.D. from Washington State University in 1974 he had a long teaching career at Montana State University. Dr. Roll conducted archaeological field projects in many parts of the state with a substantial portion of that time devoted to examination of prehistoric bison procurement in the Northwestern Plains. During his career Dr. Roll has also made substantial contributions to Plains tipi ring studies and aboriginal lifestyles and adaptations in the Rocky Mountains of northwestern Montana.

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